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09 JAN 1990

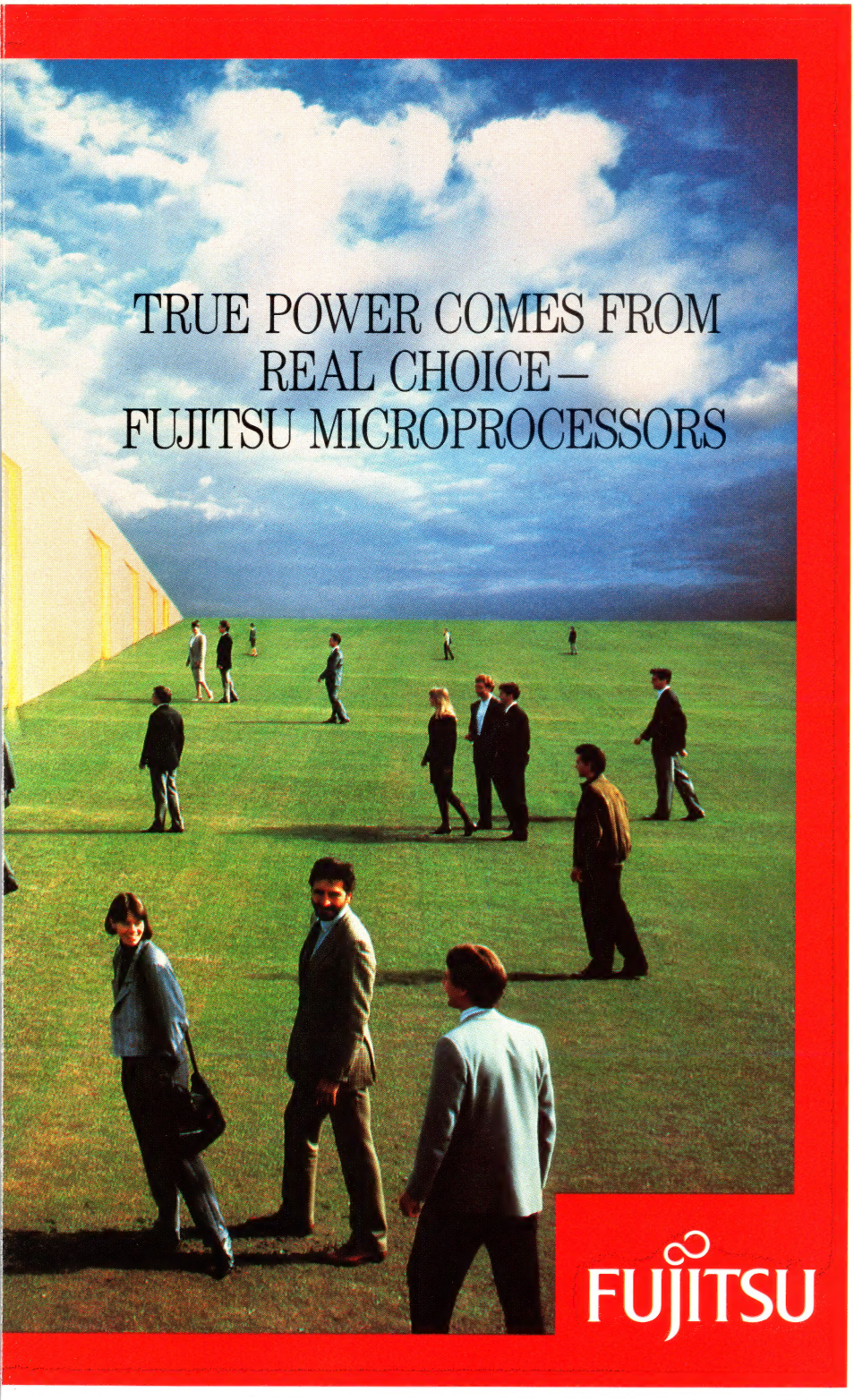
EDN®

SPECIAL ISSUE—Part 2
Product Showcase No. 30

Highlighting key trends in instruments, computers & peripherals, CAE, and components

Expanded literature section

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



These two important facts should influence your choice of microprocessor supplier:

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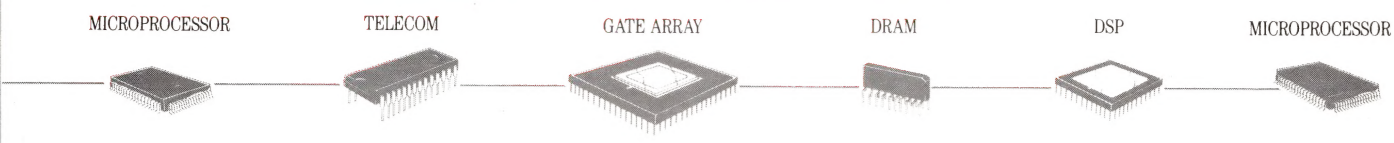
To find out more about the Fujitsu range and about development support and training, call or fax your local Fujitsu office now for a free copy of their latest microprocessor selector guide – then make your choice.



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SPARC is a registered trademark of Sun Microsystems, Inc. TRON = The Real Time Operating systems Nucleus.

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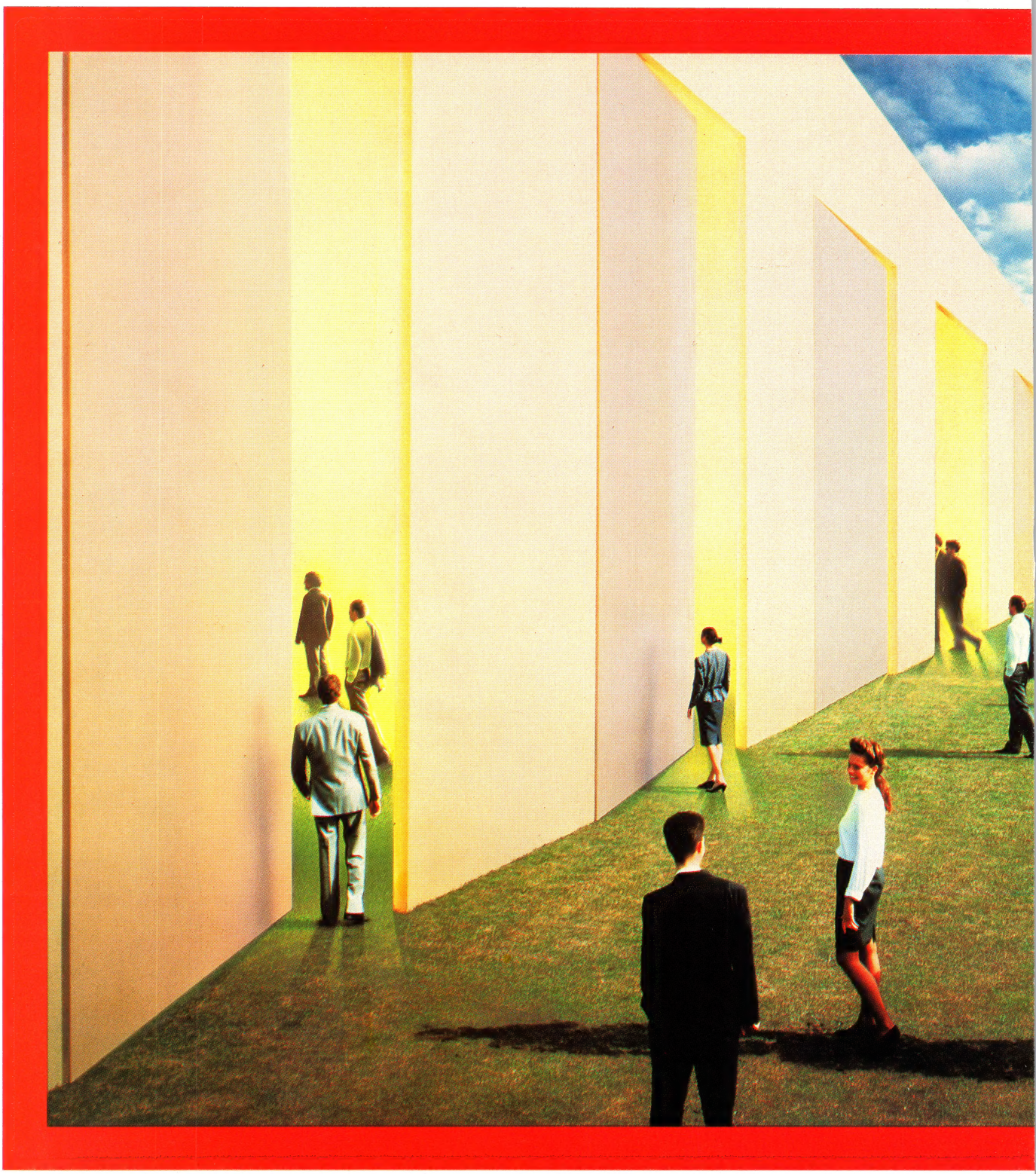

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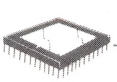

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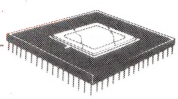

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EPROM

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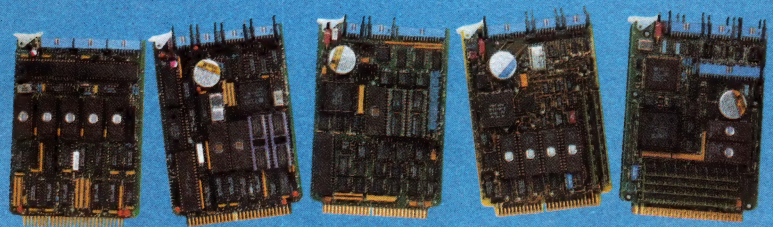

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Its specs are extraordinarily good. Just look at the 3304's operating temperature range (–55 to +125°C) and its temperature coefficient (±200ppm/°C).

And maybe most extraordinary of all is its availability from every Bourns distributor. You see, this small, inexpensive trimmer is already available off-the-shelf from: Hamilton/Avnet • TTI Schweber • Pioneer • Hall-Mark Radio Electronics Service Company JMar Electronics • ITT Components Gerber Electronics.

No matter how you measure it, Bourns 3304 comes out on top. Extraordinary.

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Circle No. 102

EDN122189

If you can use these simple tools, you can create any waveform.

The Model 75 Arbitrary Waveform/Function Generator lets you create and edit waveforms which it reproduces with digital precision. It's easy to do, because you use a thumb-tack and rubberband editing system to stretch and shape the waveform on the x-y axis while you watch the results on your oscilloscope.

No other arbitrary generator lets you design waveforms from the front panel this way.

You can also download and modify computer-generated waveforms. Or use one of the nine built-in functions. The Model 75 memory provides a grid of 8,000 horizontal and 4,000 verticai points for reproducing signals with amazing purity.

You can see that Model 75 is the wave of the future. And it has a price that makes it affordable now!

For literature or a hands-on demonstration of Model 75, call (619) 279-2200.

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Circle 105 for Literature
Circle 106 for Demonstration

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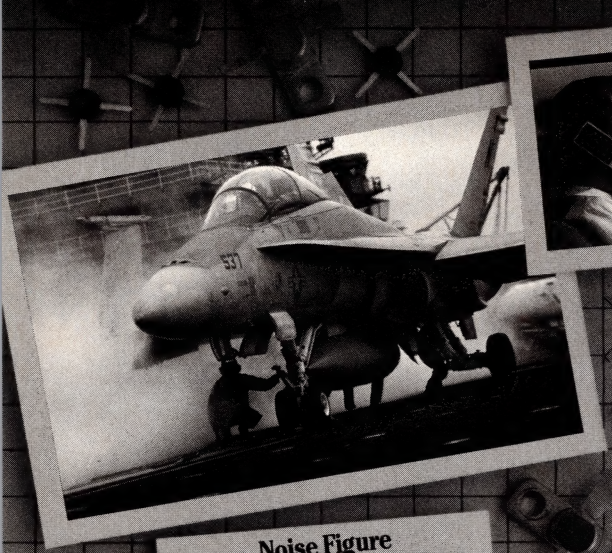

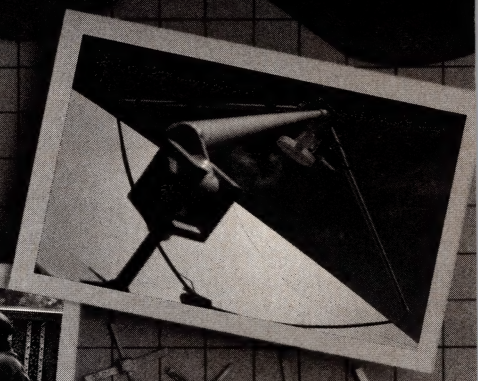

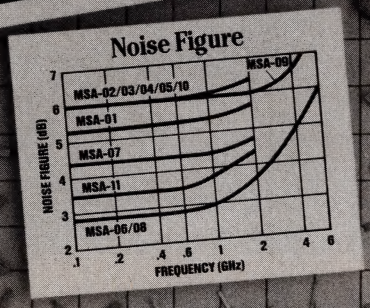

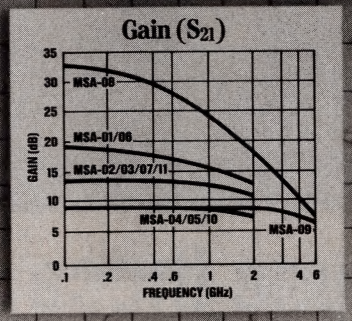

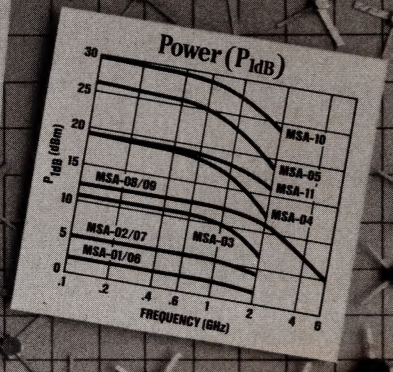

Avantek Offers the Widest Selection of Wideband Silicon MMIC Amplifiers

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CIRCLE NO 121

EDN Magazine Edition

Volume 34, Number 26 December 21, 1989

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

On the cover: *Part 2 of EDN's Product Showcase No. 30 covers a multitude of products in four technology areas: components, instruments, computers and peripherals, and computer-aided engineering. The staff-written analyses that lead off each product section focus on DIP switches (pg 44), high-performance DSOs (pg 78), PC-based single-board computers (pg 112), and simulators for high-speed board design (pg 152). (Cover photography by Kevin Bryan; art direction by Pat Crowell and Ken Racicot)*

DESIGN FEATURES

Components

DIP switches satisfy high-density pc-board design needs **44**

As designers strive to increase board density, DIP switches continue to gain popularity. These devices consume minimal board real estate, are compatible with automatic-insertion equipment, and handle high soldering temperatures.—*Tom Ormond, Senior Editor*

Instruments

Cut through the confusion surrounding high-performance DSOs **78**

As DSO manufacturers struggle for ever-higher bandwidths, sample rates, resolutions, and processing features, they are also trying to come up with the right blend of these features at the right price.—*Doug Conner, Regional Editor*

Computers and Peripherals

PC-based single-board computers invade embedded systems **112**

New μPs have extended the IBM PC's architecture far beyond the orignal personal computer's design. A wide range of hardware and software products lets you use PCs as low-cost development tools and exploit this family of architectures in your embedded-system designs.—*Steven H Leibson, Senior Regional Editor*

Computer-Aided Engineering

Simulators for high-speed board design spot trouble **152**

If you design digital boards with clock speeds greater than 25 MHz, you should consider software that performs transmission-line and crosstalk analysis of your circuit design.—*Margery Conner, Regional Editor*

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VBPA ABP

The FS700 LORAN-C frequency standard

10 MHz cesium stability

$4950

Cesium long term stability at a fraction of the cost

Better long-term stability than rubidium

Not dependent on ionosphere position changes, unlike WWV

Complete northern hemisphere coverage, unlike GPS.

The FS700 LORAN-C frequency standard provides the optimum, cost-effective solution for frequency management and calibration applications. Four 10 MHz outputs from built-in distribution amplifiers provide cesium standard long-term stability of 10^{-12}, with short-term stability of 10^{-10} (10^{-11} optional). Reception is guaranteed in North America, Europe and Asia.

Since the FS700 receives the ground wave from th LORAN transmitter, reception is unaffected by atmos pheric changes, with no possibility of missing cycles, common occurrence with WWV due to discontinuou changes in the position of the ionosphere layer. Cesium an rubidium standards, in addition to being expensive in tially, require periodic refurbishment, another costly item

The FS700 system includes a remote active 8-foo whip antenna, capable of driving up to 1000 feet of cable The receiver contains six adjustable notch filters and a fre quency output which may be set from 0.01 Hz to 10 MHz i a 1-2-5 sequence. A Phase detector is used to measure th phase shift between this output and another front pane input, allowing quick calibration of other timebases. A analog output with a range of ±360 degrees, provides voltage proportional to this phase difference for drivin strip chart recorders, thus permitting continuous mon toring of long-term frequency stability or phase locking o other sources.

FS700: The optimum frequency management system

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Your ideas, your inventions, and your legal rights. Part 2 of this 2-part article focuses on copyrights, patents, trademarks, and the Semiconductor Chip Protection Act.—*Jay Fraser, Associate Editor*

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A product-oriented design aid

To save you time in your efforts to keep current, EDN's editors have surveyed the new-product offerings from thousands of companies, screening and selecting only the most significant of those offerings introduced in the last six months. We present our findings—the best of the best—in a format devised to make your product selection as easy as possible. You can keep this Product Showcase as a reference until the next one that covers these four key product areas appears in July.

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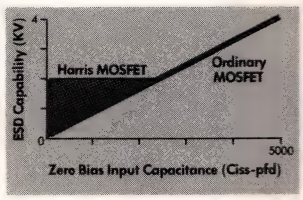
Harris announces power MOSFETs with ESD protection at a price that will shock the competition.

Harris' new logic level 3055 series power MOSFETs resist electrostatic charges. And the price will shock the competition. Because Harris 3055s with ESD protection cost no more than competitive devices without it.

A shocking breakthrough.

Our new logic level 3055 series power MOSFETs are protected to a minimum of 2 KV of electrostatic discharge. But that's not all. They're ruggedized to withstand circuit-induced



electrical stress in the breakdown avalanche mode of operation. Plus their reduced gate-drive requirement permits ON/OFF switching directly at the 5V logic level.

All of which makes them perfect for such applications as motor controls, power supplies, automotive cruise controls, solenoid drivers, regulators and more.

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Yet, for all their advantages, the new Harris logic level 3055 series power MOSFETs cost no more than competitive devices. As low as 25 cents in quantity.

And they're available today in both D-pak and TO-220 packages. For more information and samples, just give us a call at 1-800-4-HARRIS, ext. 1001 (in Canada, 1-800-344-2444, ext. 1001). Or call your local Harris sales office or distributor.

Committed to power.

Our new 3055 MOSFETs are just one of 24 new chips we've introduced this year alone. And with nearly $10 million in R&D, and a new 6-inch wafer fab, look to us to put more power in your future.

What your vision of the future demands. Today.

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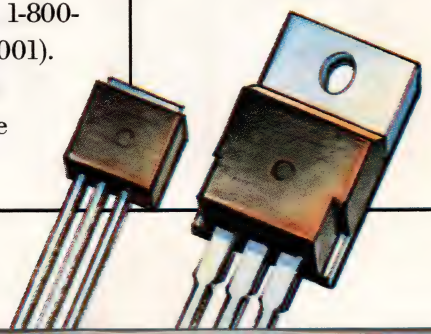

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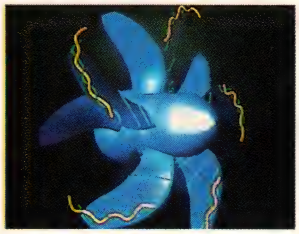
Top 40 programming. Now

Mechanical computer-aided engineering

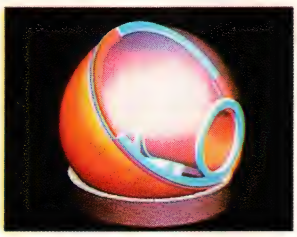
Computer-aided imaging and animation



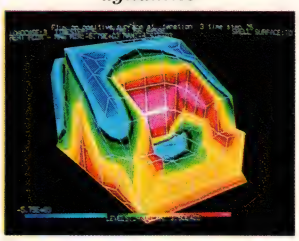
Computational fluid dynamics

Video animation production

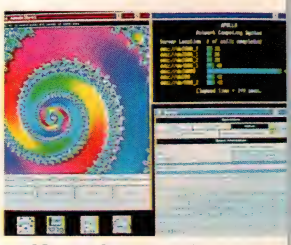
Video animation



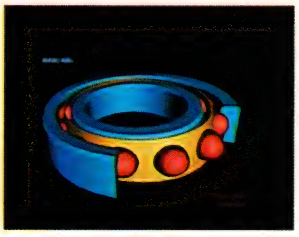
Computer-aided engineering



Finite element modeling and analysis



Network computing and mathematics



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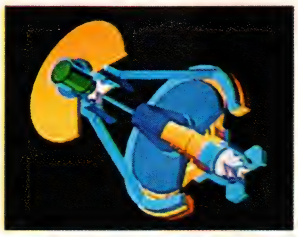
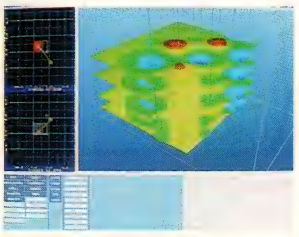
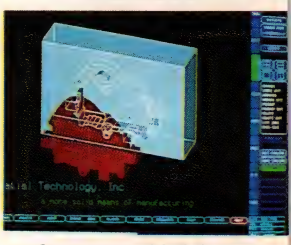


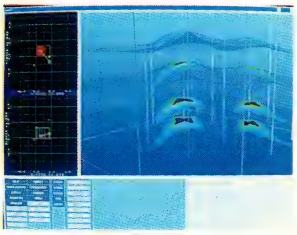
Aerospace engineering



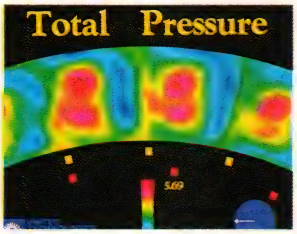
Seismic analysis



Computer-aided design in manufacturing



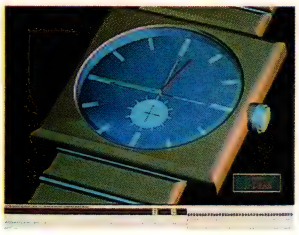
Reservoir analysis



Computational fluid dynamics

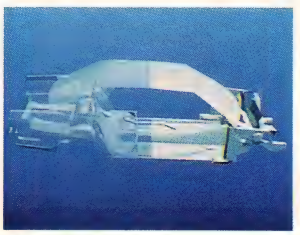
Industrial design

Computer-aided engineering



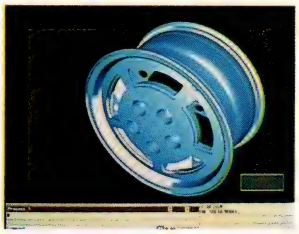
Computer-aided engineering and industrial design

Mechanical computer-aided engineering

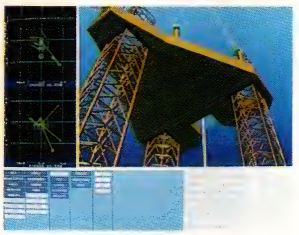


Automotive industrial design

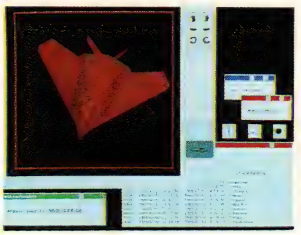
Animation



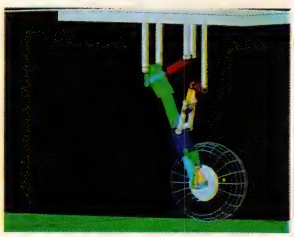
Mechanical design



Scientific visualization



Aerospace engineering



Kinematics and dynamics

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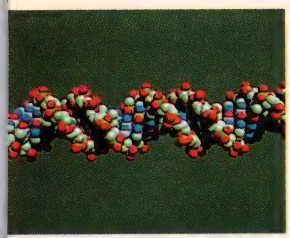
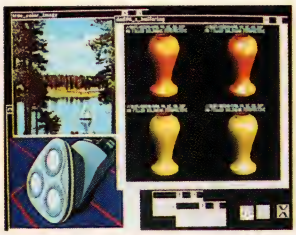
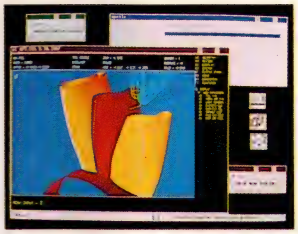


Computer-aided molecular design

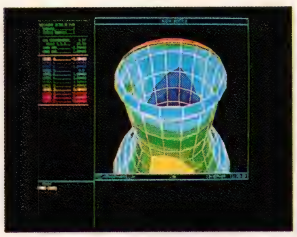


Multi-window industrial design

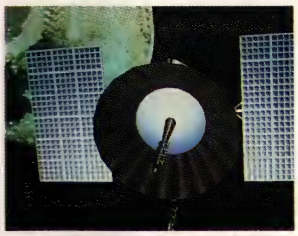


Computer-aided engineering and design

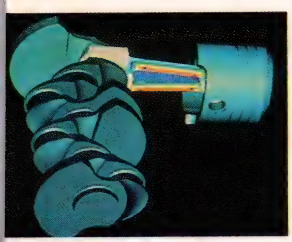
Industrial design



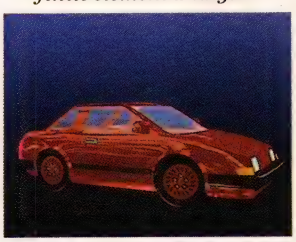
Structural analysis using finite element analysis



Aerospace engineering

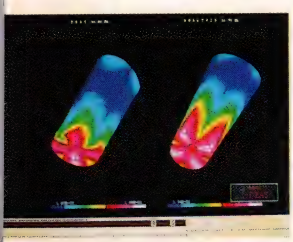


Computer-aided engineering

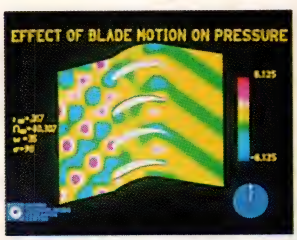


Automotive engineering

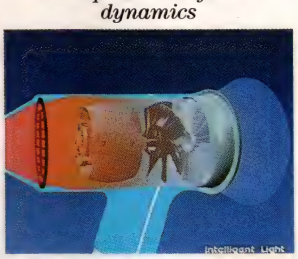
Computational fluid dynamics



Thermal analysis

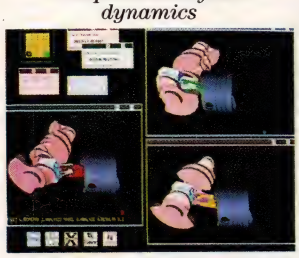


Computational fluid dynamics

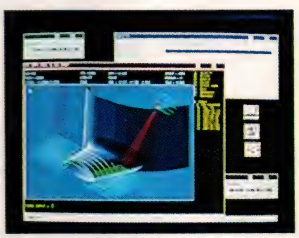


Industrial design

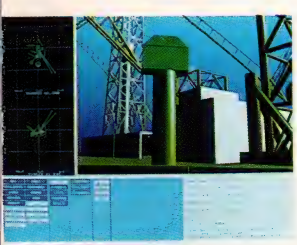
Industrial design



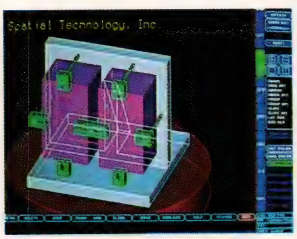
Computer-aided engineering



Computer-aided engineering



Scientific visualization



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CIRCLE NO 40

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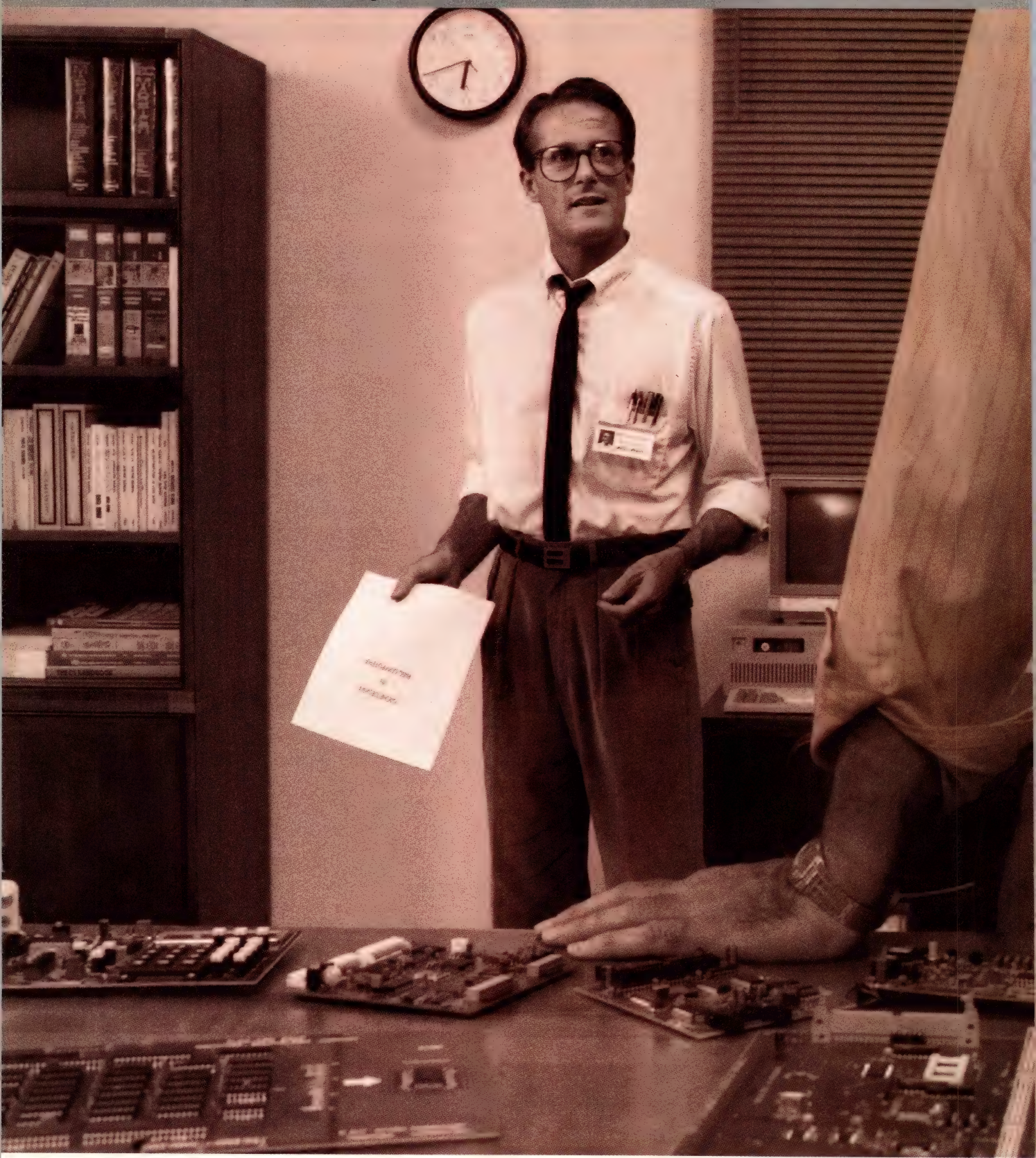

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8K x 8	64K	15	20	25		Now
8K x 9	72K	15	20	25		Now
64K x 4	256K	20	25	35		Early '89
64K x 4 (OE)	256K	20	25	35		Early '89
32K x 8	256K	20	25	35		Early '89
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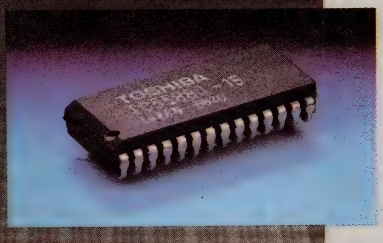

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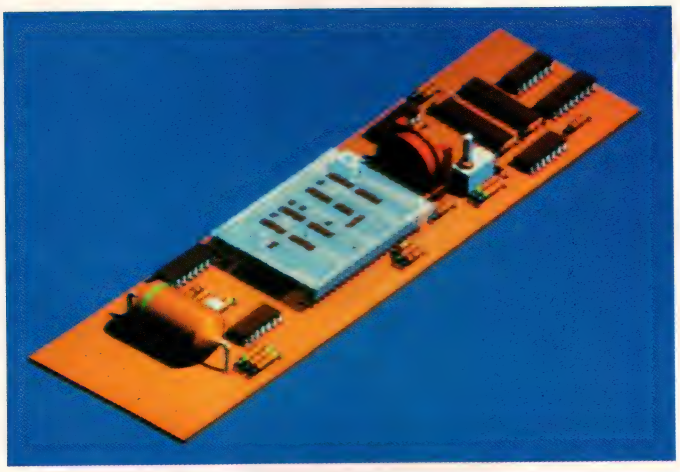

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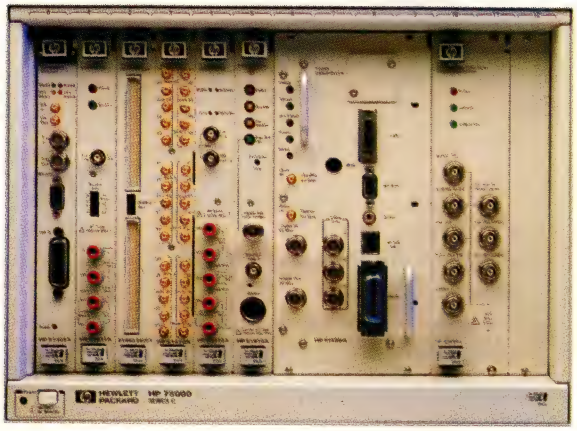
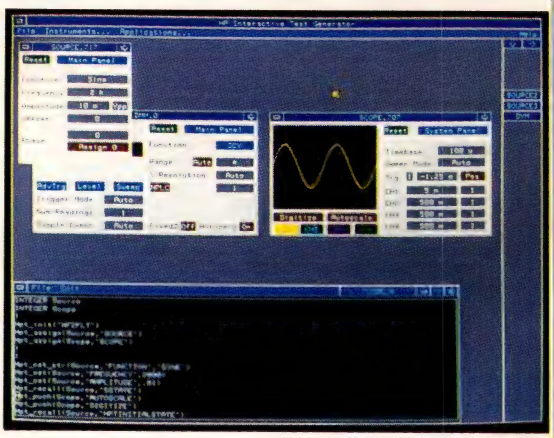
CIRCLE NO 44

"If all VXI systems are equal, how can one add up to faster test development?"





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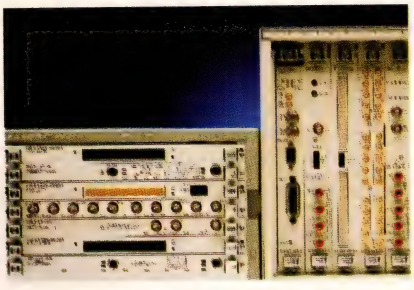

*The HP 75000 VXI is part of HP's Measurement System Architecture.

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CIRCLE NO 43

NEWS BREAKS

EDITED BY JULIE ANNE SCHOFIELD

RISC-μP VENDOR OFFERS PREFAB WORKSTATION

In an attempt to make designing RISC-based workstations as easy as designing IBM PC clones, Fujitsu Microelectronics Inc's Advanced Products Div (San Jose, CA, (408) 922-9000) commissioned a SPARC-based, 3-board workstation; a Unix implementation; and a mother-board chip set. Fujitsu provides a complete manufacturing package for the board set including schematics, bills of materials, and board photoplots for $150,000 to $300,000.

The board set comprises a CPU board, a memory board, and a peripheral board, all of which communicate over the VMEbus. The board set's display output is compatible with Sun Microsystems Inc's Sun 4 workstations. Interactive's (Santa Monica, CA, (213) 453-8649) Unix port for the board set costs $500 to $550 per copy. In addition, VIA Technologies Inc (Fremont, CA, (415) 651-2796) is integrating the board set into a set of chips similar in concept to PC-mother-board chip sets. Fujitsu expects to offer these ICs and a new manufacturing package based on the chips by the end of 1990.—Steven H Leibson

JELLYBEANS GO BiCMOS

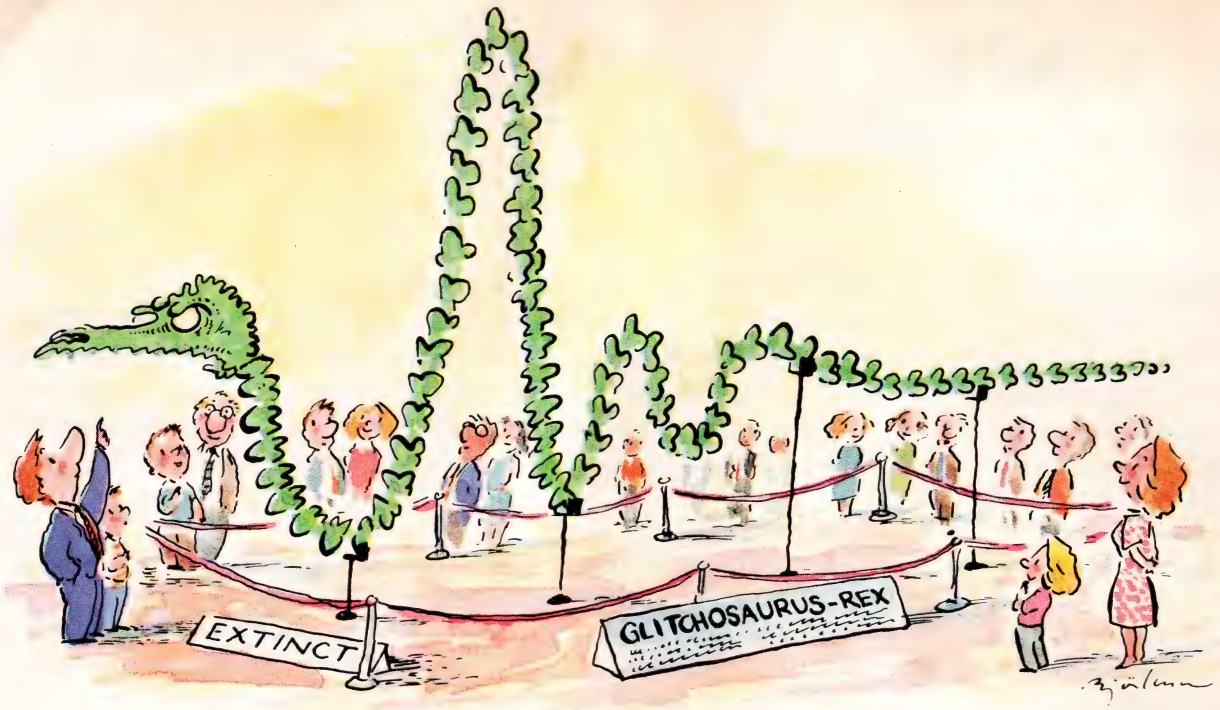
Those old standby 7400 series parts, which have appeared in S (Schottky), LS (Low-power Schottky), CMOS, HC (High-speed CMOS), and a whole alphabet soup of other incarnations, are getting yet another life. Harris Semiconductor (Melbourne, FL, (407) 724-3800) has announced a BiCMOS family of 13 7400 series parts. The devices are pin-for-pin replacements for industry-standard bipolar FAST logic. The devices feature typical propagation delay times of 3 to 4 nsec and can sink 48 to 64 mA, depending on device type. Their quiescent power dissipation is 200 times less than that of bipolar FAST logic. The 74FCT series parts cost between $1.21 and $1.46 (1000). Some are available now; others will be released through the second quarter of 1990. Delivery is four to six weeks ARO.—Michael C Markowitz

VXIbus USERS MEET FOR THE FIRST TIME AT ATE&I WEST

The first meeting of users of the VXIbus modular-instrumentation standard will take place on January 10, 1990, at the Automatic Test Equipment and Instrumentation Conference West in Anaheim, CA. The meeting is scheduled for 7 to 10 pm in the Balboa Room of the Disneyland Hotel. Among the activities on the agenda are product introductions and a 1¼-hour open discussion. Further information is available from Sandy Garza at National Instruments Inc (Austin, TX, (800) 433-3488).
—Dan Strassberg

PROGRAM LETS YOUR PC EMULATE AN HP2392 TERMINAL

Version 1.1 of Business Session is a Microsoft Windows-based terminal-emulation program that lets you run multiple programs. Tymlabs Corp (Austin, TX, (512) 478-0611) developed this program, which supports Hewlett-Packard's EDCL protocol and permits file transfers over X.25 lines. Version 1.1 lets you change the size of each program's window and display text fonts in a variety of sizes and colors. Business Session 1.1 sells for $299.—J D Mosley



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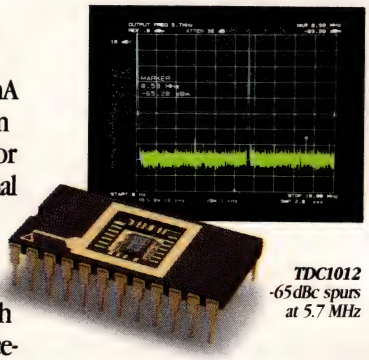

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CIRCLE NO 45

NEWS BREAKS

NEW VERSIONS OF 8-BIT μP INCORPORATE I/O DEVICES

Four new versions of the venerable Z80 μP from Zilog (Campbell, CA, (408) 370-8000) integrate a variety of I/O devices with the Z80 μP core. The Z84013 and Z84C13, which are packaged in 84-lead plastic leaded-chip carriers, include two independent, full-duplex serial I/O channels with modem control and status lines. The Z84015 and Z84C15, which are packaged in 100-lead quad flat packages, include the same serial channels and two parallel ports with an interrupt-driven handshake capability. The Z84C15 also includes a 32-bit CRC (cyclic redundancy checking) generator/checker for error-correction jobs. The Z84013 and Z84C13 cost $9 to $11 (1000), and the Z84015 and Z84C15 cost $11 to $13 (1000).—Steven H Leibson

CMOS PLDs ACHIEVE 10-nSEC PROPAGATION DELAYS

Striving to keep pace with increasing processor speeds while reducing power demands, both Intel (Folsom, CA, (916) 351-8080) and National Semiconductor (Santa Clara, CA, (408) 721-5000) have developed CMOS PLDs with propagation delays of 10 nsec.

Intel's device, the 85C220, is a UV-erasable pin-for-pin replacement for a variety of standard 20-pin PLDs. Its eight I/O lines have a programmable architecture, thus letting you create registered and combinatorial output signals. The device has a 10-nsec propagation delay using internal feedback and can operate with clocks to 80 MHz when using external feedback. It costs $7.95 (1000) in plastic DIPs and $8.35 (1000) in plastic leaded-chip carriers.

National Semiconductor has two offerings: the GAL16V8A-10 and the GAL20V8A-10. Both are electrically erasable with at least 100 erase/write cycles guaranteed. The 16V8 can emulate a variety of popular 20-pin PLDs, and the 20V8 emulates 24-pin PLDs. Both have internal propagation delays of 10 nsec and can operate with external clocks to 62.5 MHz. The 16V8 costs $7 (1000); the 20V8 costs $8.5 0 (1000). —Richard A Quinnell

LOW-COST MIL-STD-1553 INTERFACE FOR VMEBUS

The VME1553-1 interface board from Ballard Technology (Seattle, WA, (206) 782-8704) provides a complete 1553 interface on a standard double-height (6U) VMEbus card for $3500. Commercial-grade components, which keep the board's cost down, make it suitable for only nonrugged applications such as engineering development, test, and commercial applications.—Doug Conner

TEK BUYS CDS; TAKES LEAD IN NUMBER OF VXIbus PRODUCTS

Tektronix (Beaverton, OR, (206) 253-6055) has grabbed the lead in the number of VXI products offered by acquiring Colorado Data Systems (Englewood, CO). Both firms are founding members of the consortium that developed the VXIbus spec. Tek's own VXI offerings exceeded a dozen models before the instrument manufacturer announced its purchase of CDS, whose VXI catalog features more than two dozen entries. In terms of number of VXI offerings, another founding member of the VXI consortium, Hewlett-Packard (Loveland, CO, (800) 752-0900), with approximately 30 in-house-developed VXI products, slips to second place behind its Oregon-based archrival . . . at least for the moment.—Dan Strassberg

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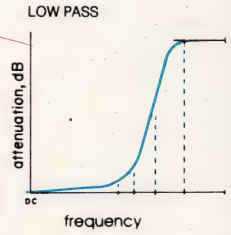

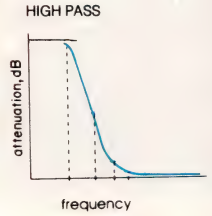

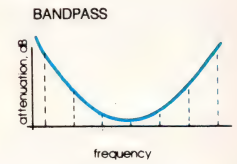

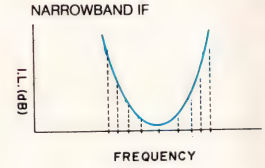

low pass dc to 1200MHz

MODEL NO.	PASSBAND, MHz (loss <1dB) Min.	fco, MHz (loss 3db) Nom.	STOP BAND, MHz (loss>20dB) Max.	(loss>40dB) Max.	Min.	VSWR pass-band typ.	stop-band typ.	PRICE $ Qty. (1-9)
PLP-10.7	DC-11	14	19	24	200	1.7	18	11.45
PLP-21.4	DC-22	24.5	32	41	200	1.7	18	11.45
PLP-30	DC-32	35	47	61	200	1.7	18	11.45
PLP-50	DC-48	55	70	90	200	1.7	18	11.45
PLP-70	DC-60	67	90	117	300	1.7	18	11.45
PLP-100	DC-98	108	146	189	400	1.7	18	11.45
PLP-150	DC-140	155	210	300	600	1.7	18	11.45
PLP-200	DC-190	210	290	390	800	1.7	18	11.45
PLP-250	DC-225	250	320	400	1200	1.7	18	11.45
PLP-300	DC-270	297	410	550	1200	1.7	18	11.45
PLP-450	DC-400	440	580	750	1800	1.7	18	11.45
PLP-550	DC-520	570	750	920	2000	1.7	18	11.45
PLP-600	DC-580	640	840	1120	2000	1.7	18	11.45
PLP-750	DC-700	770	1000	1300	2000	1.7	18	11.45
PLP-800	DC-720	800	1080	1400	2000	1.7	18	11.45
PLP-850	DC-780	850	1100	1400	2000	1.7	18	11.45
PLP-1000	DC-900	990	1340	1750	2000	1.7	18	11.45
PLP-1200	DC-1000	1200	1620	2100	2500	1.7	18	11.45

high pass dc to 2500MHz

MODEL NO.	PASSBAND, MHz (loss <1dB) Min.	Min.	fco, MHz (loss 3db) Nom.	STOP BAND, MHz (loss>20dB) Min.	(loss>40dB) Min.	VSWR pass-band typ.	stop-band typ.	PRICE $ Qty. (1-9)
PHP-50	41	200	37	26	20	1.5	17	14.95
PHP-100	90	400	82	55	40	1.5	17	14.95
PHP-150	133	600	120	95	70	1.8	17	14.95
PHP-175	160	800	140	105	70	1.5	17	14.95
PHP-200	185	800	164	116	90	1.6	17	14.95
PHP-250	225	1200	205	150	100	1.3	17	14.95
PHP-300	290	1200	245	190	145	1.7	17	14.95
PHP-400	395	1600	360	290	210	1.7	17	14.95
PHP-500	500	1600	454	365	280	1.9	17	14.95
PHP-600	600	1600	545	440	350	2.0	17	14.95
PHP-700	700	1800	640	520	400	1.6	17	14.95
PHP-800	780	2000	710	570	445	2.1	17	14.95
PHP-900	910	2100	820	660	520	1.8	17	14.95
PHP-1000	1000	2200	900	720	550	1.9	17	14.95

bandpass 20 to 70MHz

MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz (loss <1dB) Max. F1	Min. F2	STOP BAND, MHz (loss > 10 dB) Min. F3	Max. F4	(loss > 20 dB) Min. F5	Max. F6	VSWR 1.3:1 typ. total band MHz	PRICE $ Qty. (1-9)
PIF-21.4	21.4	18	25	4.9	85	1.3	150	DC-220	14.95
PIF-30	30	25	35	7	120	1.9	210	DC-330	14.95
PIF-40	42	35	49	10	168	2.6	300	DC-400	14.95
PIF-50	50	41	58	11.5	200	3.1	350	DC-440	14.95
PIF-60	60	50	70	14	240	3.8	400	DC-500	14.95
PIF-70	70	58	82	16	280	4.4	490	DC-550	14.95

narrowband IF

MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz I.L. 1.5dB max. F1-F2	STOP BAND, MHz I.L. > 20dB F5	F6	STOP BAND, MHz I.L. > 35dB F7	F8-F9	PASS-BAND VSWR Max.	PRICE $ Qty. (1-9)
PBP-10.7	10.7	9.5-11.5	7.5	15	0.6	50-1000	1.7	18.95
PBP-21.4	21.4	19.2-23.6	15.5	29	3.0	80-1000	1.7	18.95
PBP-30	30.0	27.0-33.0	22	40	3.2	99-1000	1.7	18.95
PBP-60	60.0	55.0-67.0	44	79	4.6	190-1000	1.7	18.95
PBP-70	70.0	63.0-77.0	51	94	6	193-1000	1.7	18.95

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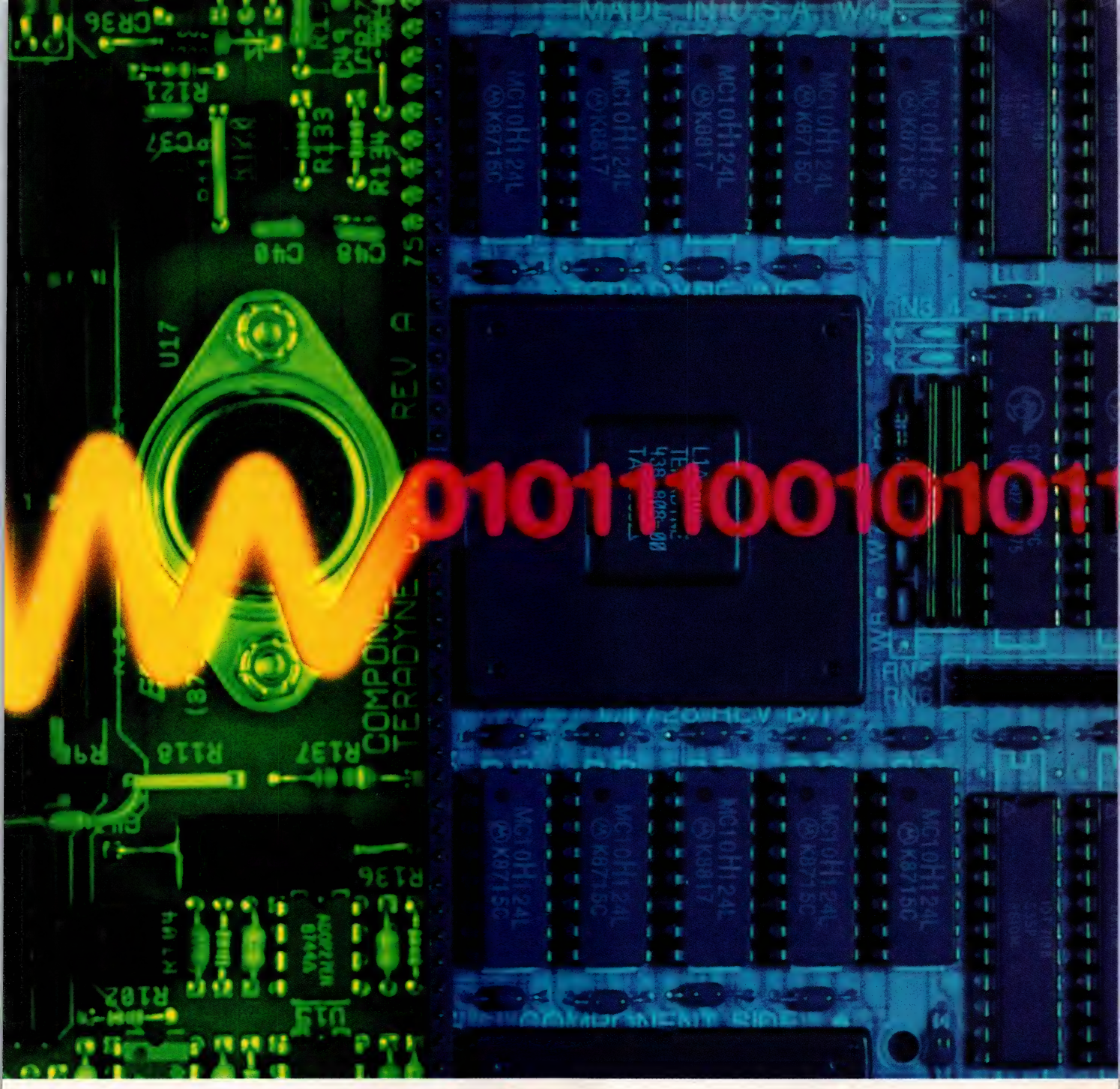

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Gremlins attack VXIbus table

Gremlins attacked the **table** of VXIbus products (EDN, November 23, 1989, pg 51). On pg 62, three Tektronix modules (models VXI-5520, VX15530, and VX15535) were shown as products of NH Research. These units, together with Universal Test Equipment's VX-57, VX-53, and VX-54, were listed under "Frequency-domain measurements," but they belong in the "Computers, slot-0 boards, peripherals" category.

Seven products, Giordano Associates' A1028, Hewlett-Packard's E1330A and E1364A, NH Research's 81302, Tektronix's VX1-4440, and Universal Test Equipment's VX-86 and VX-83, appear incorrectly under "Computers, slot-0 boards, and peripherals." They should be classified as "Digital I/O, pin drivers/receivers."

A category heading, "Frequency/time-interval counters" was accidentally omitted. The last two products on pg 62, Colorado Data Systems' 73A-541 and 73A-993, should be classified as counters, as should the first seven products appearing at the top of pg 64. All of these last nine units were incorrectly listed as "Digital I/O, pin drivers/receivers."

Finally, in the **box** on pg 58, a note indicating that Gepac Inc is the US distributor for VXI products made by Evira sa was omitted.

Reader points out missing junction

I've greatly enjoyed reading Bob Pease's amusing and informative series on troubleshooting analog circuits. However, I believe there's an error in the boost power-supply circuit in Part 11 (EDN, October 12, 1989, pg 182, **Fig 1**). There is no path shown for the base drive current to the 2N2210 transistor. Because this transistor serves to turn off the main power switch at the end of the switching cycle, I'm not sure any amount of soft start would prevent this configuration from blowing up at turn-on. I believe the intention was to connect the C_A and C_B pins of the 3524 to the bottom end of the 2k pullup resistor and to the anode of the 1N914 driving the base of the 2N2210.

Steve Mowry
Texas Instruments Inc
Johnson City, TN

(Ed Note: Bob Pease agrees with Steve Mowry. A junction should have been indicated in **Fig 1** *to tie C_A to C_B. Bob also points out that the inductor should be labeled 300 μH rather than 300 μM. EDN apologizes to its readers.)*

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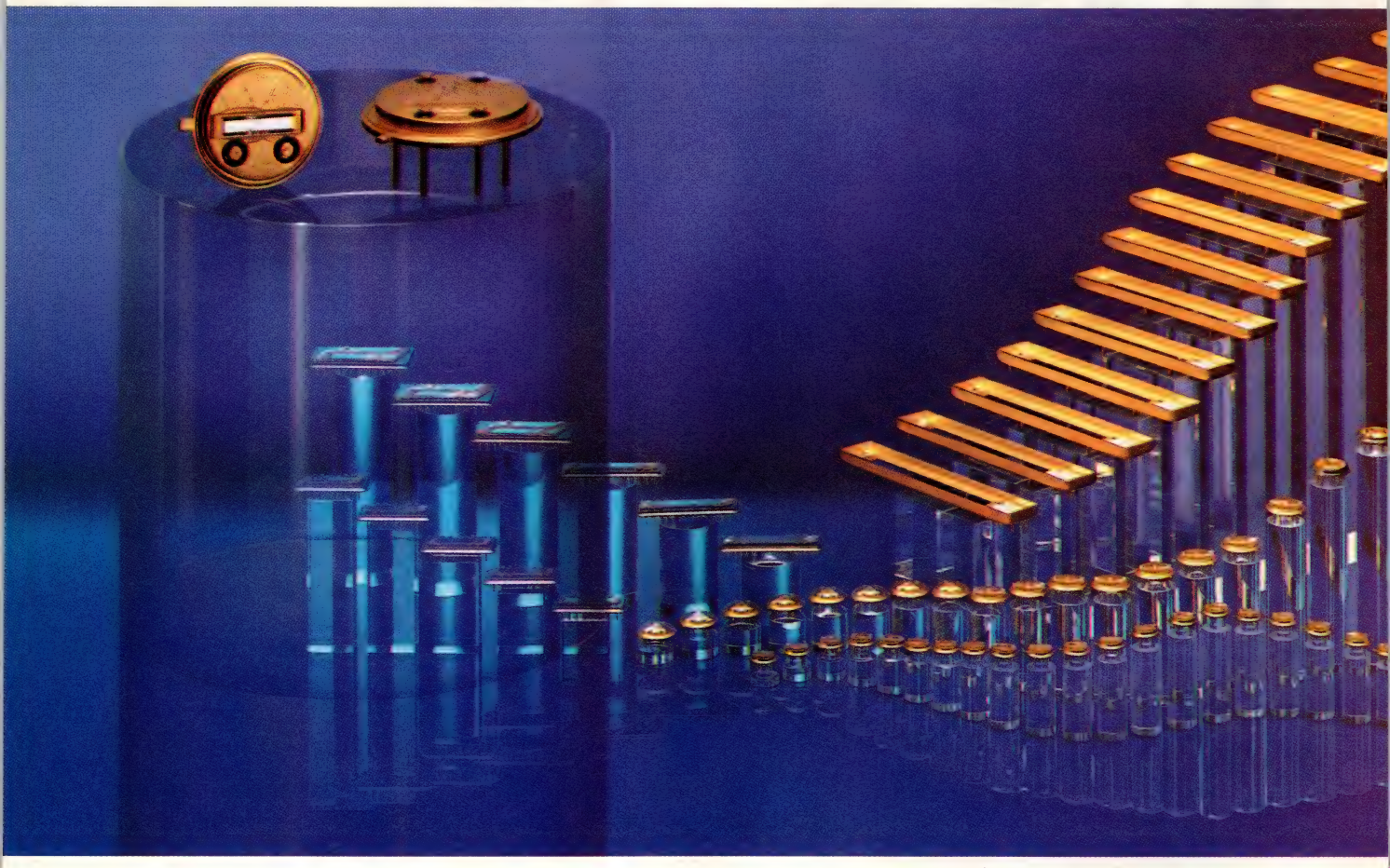

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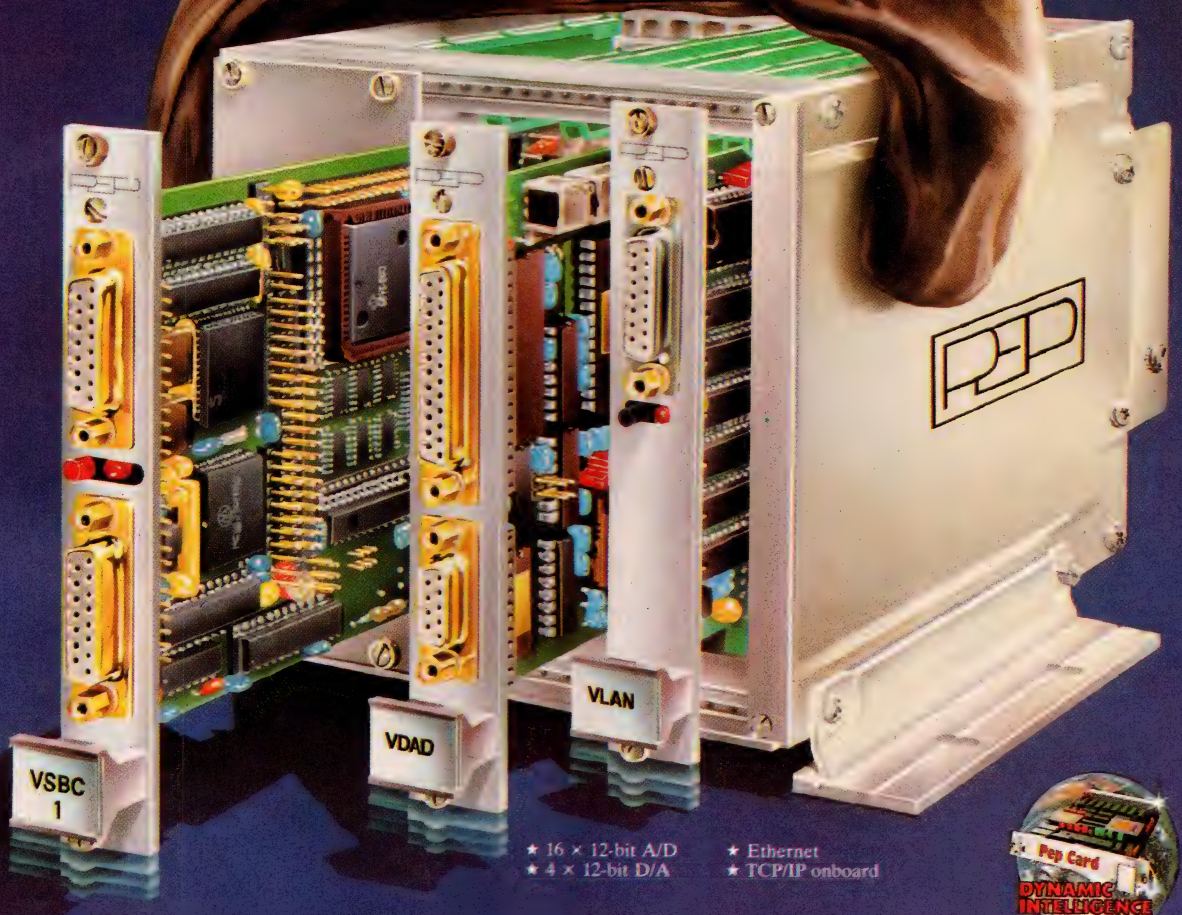

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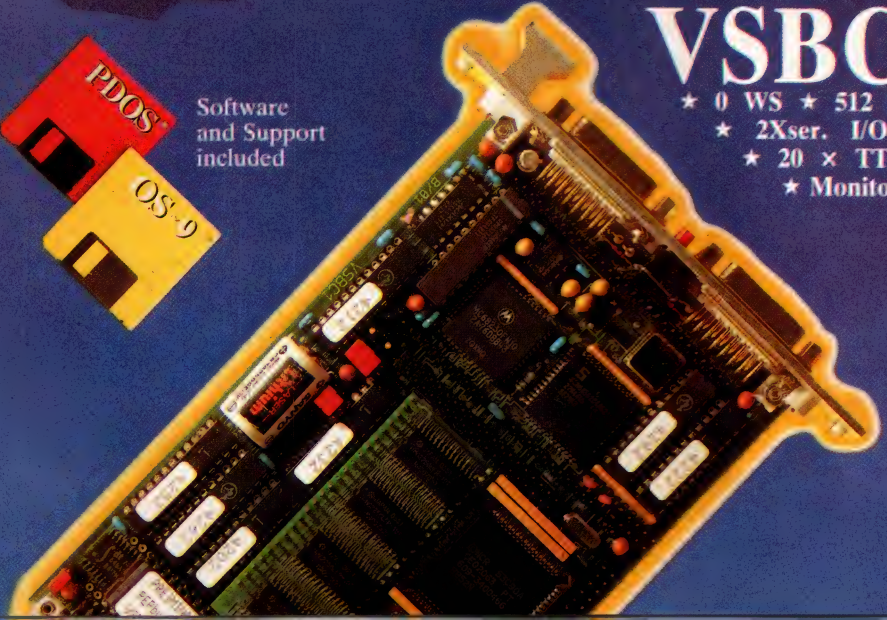

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At the 4front of 4

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Device	Organization	Access Mode	Access Time MAX. (ns)
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MSM514400-8XX MSM514400-10XX	1M x 1	Fast Page	80 100
MSM514402-8XX MSM514402-10XX	1M x 1	Static Column	80 100
Packaging Options Include: XX = 'JS'...350 mil SOJ 'RS'...400 mil DIP 'ZS'...400 mil ZIP			
MSC2340-XY59 Speed Options Include: X = '8'...80 ns. '10'...100 ns.	4M x 9	Fast Page	80, 100

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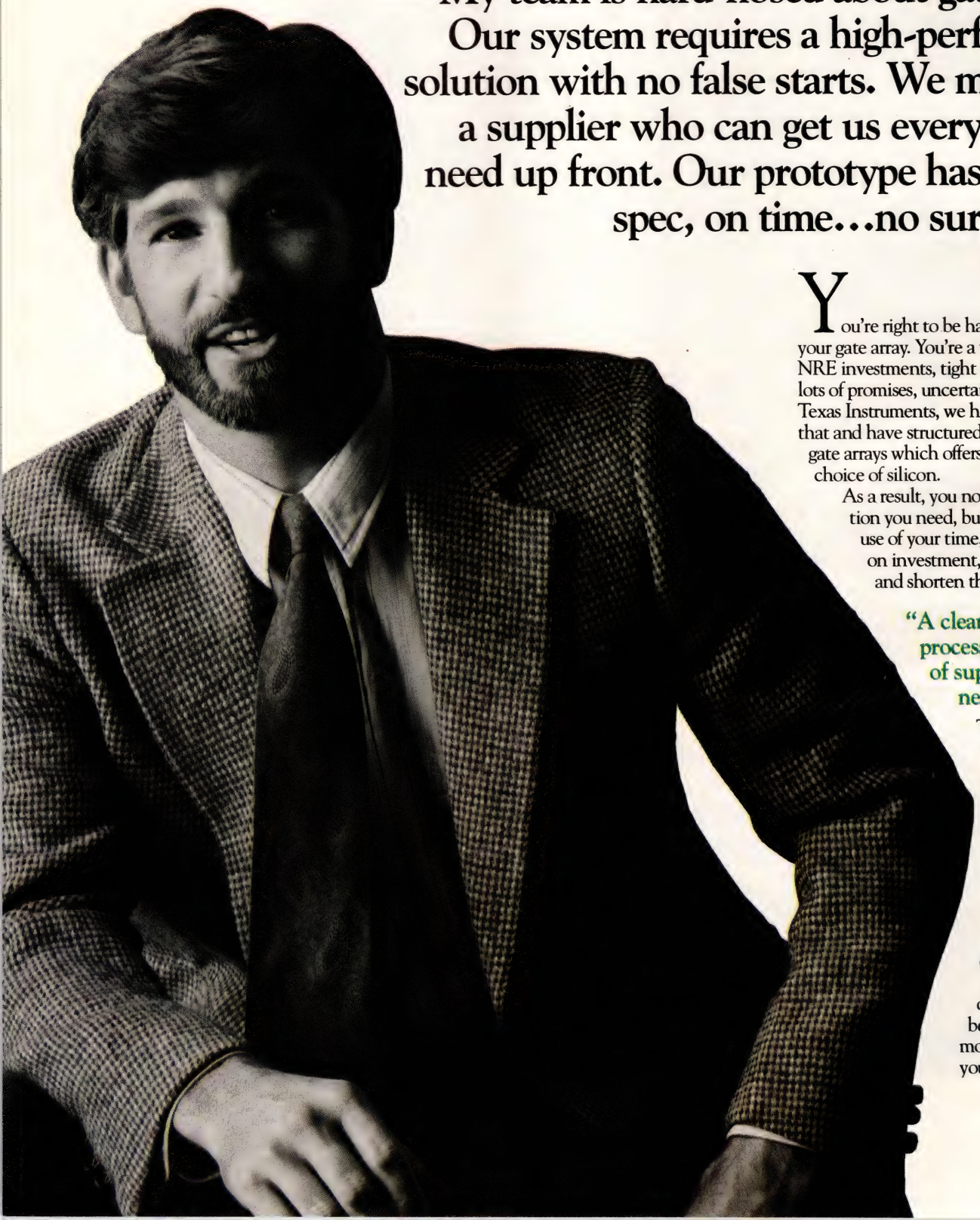
CIRCLE NO 52

TEXAS INSTRUMENTS REPORTS ON

ASIC SOLUTIONS

IN THE ERA OF MEGACHIP™ TECHNOLOGIES

"My team is hard-nosed about gate arrays. Our system requires a high-performance solution with no false starts. We must have a supplier who can get us everything we need up front. Our prototype has to be on spec, on time...no surprises."



You're right to be hard-nosed about your gate array. You're a veteran of high NRE investments, tight market windows, lots of promises, uncertain results. At Texas Instruments, we have anticipated that and have structured an approach to gate arrays which offers you more than a choice of silicon.

As a result, you not only get the solution you need, but you make better use of your time, improve return on investment, lessen the risks, and shorten the design cycle.

"A clear-cut design process with plenty of support is a necessity."

TI's design flow is very straightforward. Areas of control are defined to minimize the possibility of surprises. Our goal is the same as yours — a shortened design cycle time. When necessary, our design flow can be adapted even more precisely to fit your needs.

GATE ARRAYS

TI's service and support are comprehensive — and available to you from Texas to Taiwan. Among the highlights:

Our TGC100 Series Design Kit, operating on Daisy/Cadnetix (DAZIX™), Mentor Graphics™, and Valid™ workstations, provides the necessary information to easily implement your gate-array design.

Person-to-person advice and counsel are provided worldwide by ASIC applications specialists in our field sales offices. ASIC design specialists are stationed at ASIC design centers in our Regional Technology Centers, where our design workshop is also conducted regularly.

Delivery schedules can be tailored to support your ship-to-stock or just-in-time programs anywhere in the world.

"We demand high performance in our arrays."

The TGC100 arrays are fabricated in TI's l-micron EPIC™ CMOS process technology. Typical gate delays are 500 ps with flip-flop toggle rates up to 208 MHz.

"We prefer a choice of densities plus design options."

TI's TGC100 arrays range in complexity up to 26K gates. You call the shots on pin count, pinout definition, and the package itself by choosing from our variety of packages having pin counts up to 256 pins (*see table below*).

TI's gate-array library contains more than 200 macros, many essential to attaining high-performance designs. For example, a clock distribution macro minimizes clock skew. Input/output buffer macros minimize unwanted voltage transients and drive heavy capacitive loads.

In support of the JTAG standard, SCOPE™ macros permit incorporation of design-for-test features.

A path-length criticality parameter allows you to specify the delays on critical nets. This acts to minimize the physical length of the interconnect traces and reduce overall propagation delay.

When you have more demanding requirements, the following options give you maximum flexibility in achieving the exact gate array you need:

- Additional prototypes
- Additional l-MHz test vectors
- Prototype devices tested over temperature and V_{CC} ranges plus DC parametrics
- Critical-path delay measurements (pin-to-pin)
- "At speed" test vectors
- Nonstandard V_{CC} and ground-pin locations
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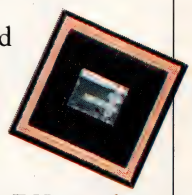
Tomorrow's outlook

Just as our TGC100 Series gate arrays meet the majority of your needs today, our gate arrays of tomorrow will fill the predominant industry needs for submicron densities.



Already, TI has disclosed an array having 106K gates, fabricated with TI's EPIC-II, 0.8-micron BiCMOS technology. High density combines with high performance — ECL speeds at CMOS power levels. This technology is the foundation for an entire family of submicron ASIC products from TI.

For more information on TI gate arrays, call, fax, or write us. **In Europe** call 44-234-223000, fax 44-234-223459, or write Customer Response Centre, MS 09, Texas Instruments Limited, Manton Lane, Bedford MK41 7PA, England. **In Japan** call 81-3-769-8700, fax 81-3-457-6777, or write Texas Instruments Japan Limited, MS Shibaura Building 9F, 4-13-23 Shibaura, Minato-Ku, Tokyo 108, Japan. **In Hong Kong** call 852-3-735-1223, fax 852-3-735-4954, or write Texas Instruments Hong Kong Limited, Market Communications Department, 8th Floor World Shipping Centre, 7 Canton Road, Kowloon, Hong Kong.

TI's TGC100 SERIES COMMERCIAL GATE ARRAYS

GATE-ARRAY TYPE	TOTAL CELLS	MAXIMUM USABLE (90%)	TOTAL BOND PADS	PRODUCTION PACKAGE OPTIONS: PLASTIC DIP 28	PLASTIC DIP 40	PLASTIC LEADED CHIP CARRIER 28	PLASTIC LEADED CHIP CARRIER 44	PLASTIC LEADED CHIP CARRIER 68	PLASTIC LEADED CHIP CARRIER 84	PLASTIC QUAD-FLAT PACKAGE* 80	100	120	132	144	160	208	240	PLASTIC PIN-GRID ARRAY 100	120	132	144	180	208	256
TGC104	3,600	3,240	100	X	X	X	X	X	X	•	+•							X						
TGC105A	4,500	4,050																						
TGC106	5,600	5,040	130	X	X		X	X	X	•	+•	•	+					X	X	X				
TGC107	6,720	6,048																						
TGC108A	8,340	7,506	158	X	X		X	X	X	•	+•	•	+	•	•			X	X	X	X	X		
TGC110	10,008	9,007																						
TGC113	12,654	11,389	196					X	X			•	+	•	•	•		X	X	X	X	X	X	
TGC115A	14,706	13,235																						
TGC116	15,580	14,022	216									•	+	•	•	•	•			X	X	X	X	X
TGC119	18,620	16,758																						
TGC122	21,854	19,669	256												•	•	•					X	X	X
TGC126	25,868	23,281																						

*+ = JEDEC; • = EIAJ

Additional packaging is available for military applications.

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Report from California: Earthquake!

Richard Quinnell
Regional Editor

Regional Editor Richard Quinnell filed this report to EDN's home office on Wednesday, October 18, the day after an earthquake measuring 7.1 on the Richter scale ravaged Northern California.

APTOS, CA—We just had a major earthquake. I hope someone videotaped it so that I can see what happened. Fortunately, I don't commute to San Jose anymore. If I did, I would have been trapped there. All of the roads to the coast have been closed by landslides or collapsing bridges. As it is, I'm safe and snug at home with my family.

Earthquakes are an interesting experience. When the shaking started, my wife was standing in the doorway to my home office. Because of its extra-strong construction, a doorway is a good place to be, so I joined her. Good thing, too. The bookshelf above my desk collapsed a few moments later, spilling my library of back issues into my chair. I'd hate to have been EDN'd to death.

The quake starts out with a rumble, just as a rotten ceiling beam creaks before it lets go. Then the ground begins its dance. (I could see my cars jumping six inches off the ground.) The mind goes blank—as though your perception of the world is so suddenly altered that nothing you see makes sense. Anxiety mounts, but before it reaches a snapping point, the motion stops. You're still in shock for a few moments. Then you react. Tears and prayers of gratitude are favored responses.

The rest is pretty much like picking up the pieces from any other calamity. You look to see what was damaged, wonder about your friends and family, tune in the radio to hear how much worse off everyone else is, and begin to get on with cleaning up. The aftershocks are the spookier part. You sort of get lulled into thinking that it's all over, then the trembling begins again. After a while you get used to those, too.

We had a barbeque on the beach that evening, gathering with neighbors to talk it out and unwind—and to get well away from possible falling objects. The tremors of the aftershocks are actually kind of fun when you know there's no danger of something falling on you. The night was clear, warm, and dark. No lights anywhere.

I don't mean to minimize the magnitude of the disaster that befell the Bay area. There will be repairs going on for years. Major highways are fractured, gas and power will take days to restore (the phones were working within hours), and hidden damage will gradually be revealed, showing that more buildings were rendered useless than was obvious from the outside. There will be loss, hardship, and suffering for many.

We'll feel the effects weeks and months later. Traffic will be terrible as roads wait for repair. The price of DRAMs and PC chipsets will probably go up; real estate values will go down. You will only see the drama in the damage to material things, not the trauma of the people.

More people die in alcohol-related automobile accidents on a holiday weekend than died here. Tobacco smoking also accounts for higher death rates. Yet, we live with these evils because they are of our own choosing. Also, they don't perturb society's structure, nor affect more than a few people at a time. They are individual disasters, easily ignored.

With the earthquake we are more frightened than hurt. We are startled by its suddenness. We feel betrayed when the very earth becomes unreliable and belies our sense of mastery. The core of our personal sense of security is shaken as violently as the earth has been. Even if undamaged, your home no longer feels safe. Once solid-seeming bridges and overpasses now look like death traps. The real damage from an earthquake is to the spirit of millions who remain terrified, not the injured bodies of hundreds.

Spirits are tough, though. People began to recover moments after the shaking stopped. They're helping each other, showing compassion never seen in "normal" times. And they wonder if the World Series will continue tomorrow. We humans refuse to accept defeat from any source. We go on.

Jesse H Neal
Editorial Achievement Awards
1987, 1981 (2), 1978 (2),
1977, 1976, 1975

American Society of
Business Press Editors Award
1988, 1983, 1981

"I'm not a writer who writes about engineering; I'm an engineer who writes."

Anne Swager, EDN Magazine Edition Associate Editor

Anne's been reading EDN since she became an electrical engineer. And as an engineer, she has always counted on EDN to keep her up to date on new products and technology in the electronic markets. "As an engineer, I found myself always focusing on one project. I read EDN to find out what was going on in other areas of electronic engineering. Becoming a technical editor gave me greater exposure to the entire spectrum of electronics."

Not too long ago, Anne saw an ad like this one and answered it. "When I saw EDN's ad, I sent in my resume. I never even considered working for another publication."

Anne doesn't see working at EDN as a career change. "As an engineer, I liked problem solving, hands-on work, and circuit design. As an EDN editor, I still keep in touch with all three engineering activities. . . I just approach them from different angles. This position lets me investigate trends and new technologies and then write about them. So, I'm not limiting my capabilities as an engineer; I'm expanding them. Before you can explain a concept to someone else, you must understand it yourself."

You too can be an engineer who writes for EDN. All you need are a BS in electrical engineering, at least two years of design experience and the ability to write clearly. Salaries are competitive with those paid to engineers.

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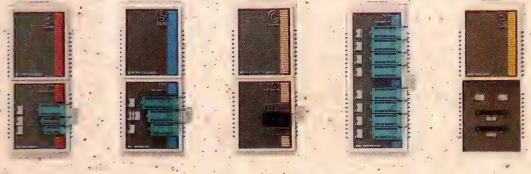
PLD PROGRAMMER

MOS PROGRAMMER

BIPOLAR PROGRAMMER

GANG SET PROGRAMMER

MEGABIT ROM EMULATOR



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PCMODE

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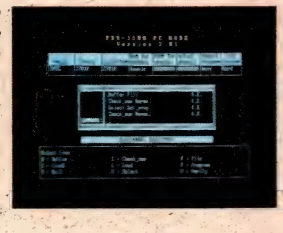

LOG/iC SYNTHESIS

LOG/iC

LOG/iC, the multipurpose design tool for universal logic synthesis, is available on most mini-and microcomputer systems. It lets you describe your design with an arbitrary mix of Equations, Truth Tables and State Machine Syntax. When you want to use graphic designs, LOG/iC's "Schematic Macro Library" supports input of netlists from third party schematic editors-such as OrCad. A Block orientated design syntax lets you define independent Macros and link them with these graphic blocks. LOG/iC's Functional Verifier then lets you simulate your design interactively on screen. The same input syntax can be optimised for different physical implementations.

AVAL CORPORATION

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6-16-6 Nishishinjuku, Shinjuku-ku, Tokyo Daisan Maruzen Bldg. 160
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CIRCLE NO 53

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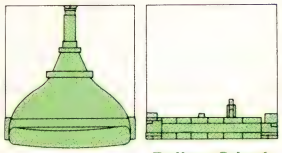

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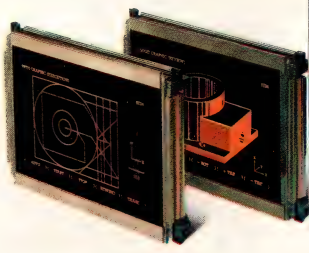
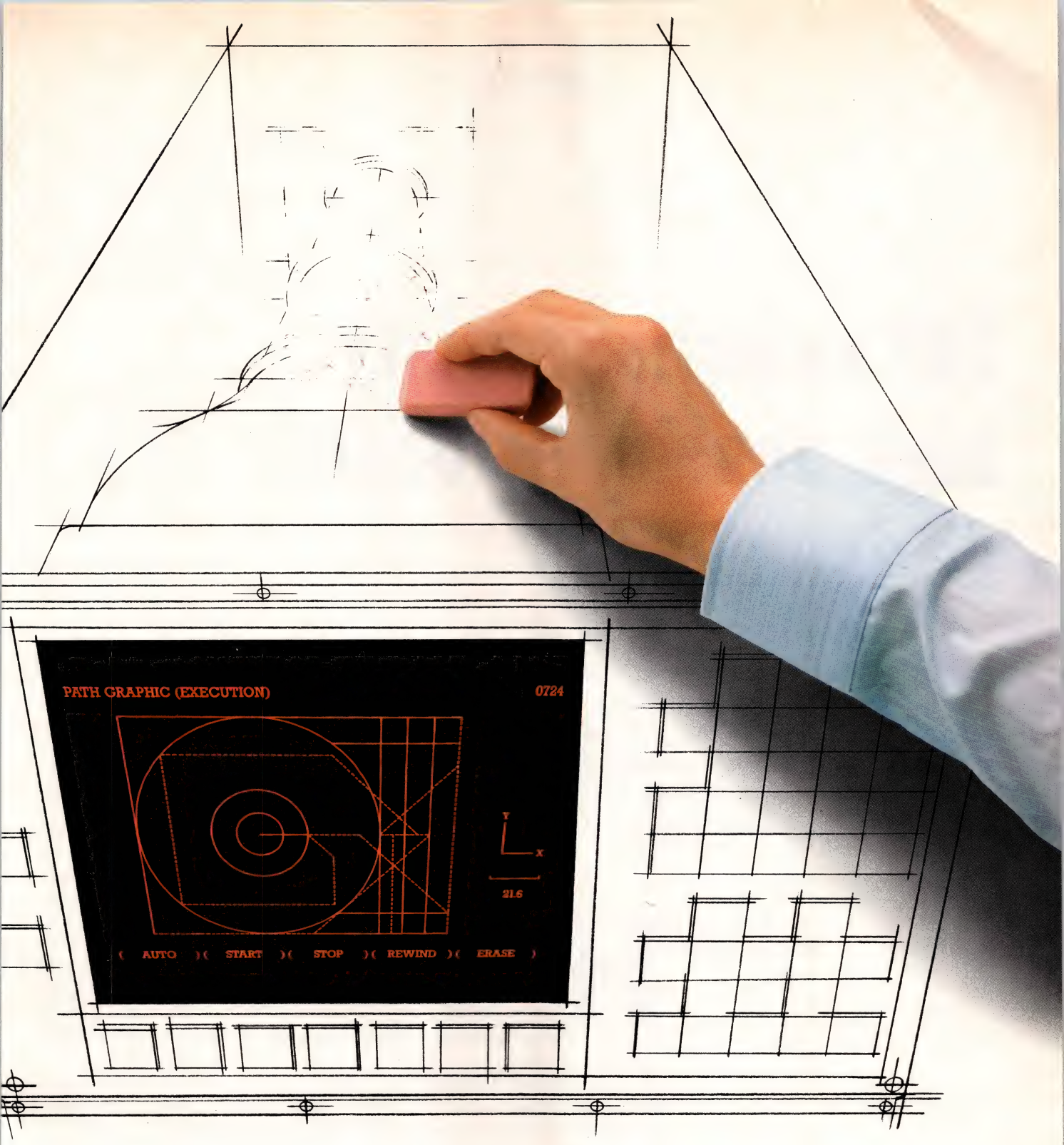


For complete information and specifications, please call Fujitsu Mikroelektronik GmbH at 069-66320.



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DIP switches satisfy high-density pc-board design needs

As designers strive to increase board density, DIP switches continue to gain popularity. Available in a variety of shapes and sizes, these devices consume minimal board real estate and are compatible with automatic-insertion equipment. Surface-mount DIP switches also handle high soldering temperatures.

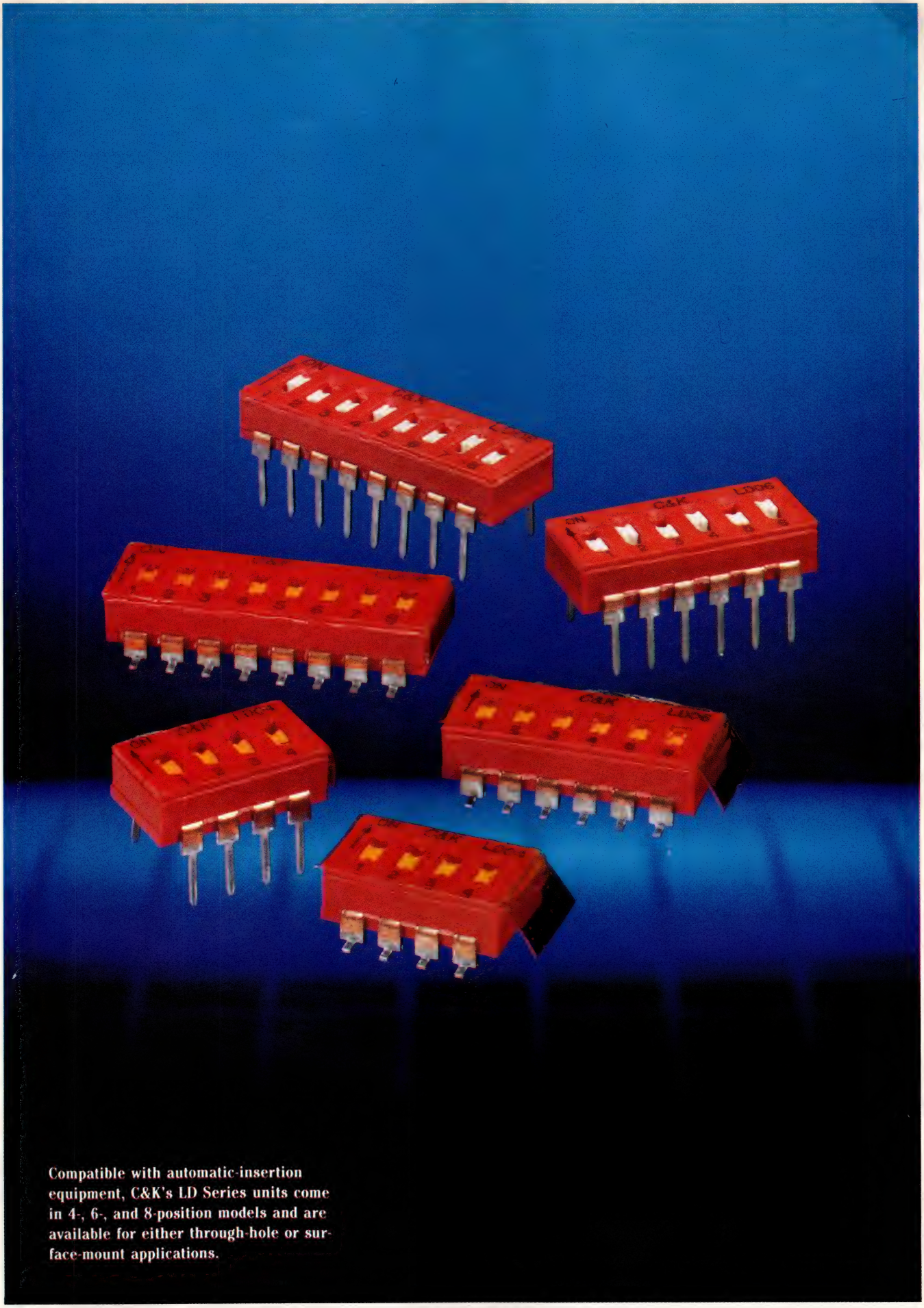
Tom Ormond,
Senior Editor

High density appears to be the primary design goal in electronics today as drive manufacturers continue to reduce disk size and increase storage capability. IC designers keep packing more and more capability into smaller packages, and circuit designers keep mounting more and more of these components onto smaller pc boards. High-density design needs will increase further if surface-mount assemblies become the rule in pc-board design. Fortunately, DIP switches can satisfy these high-density design requirements.

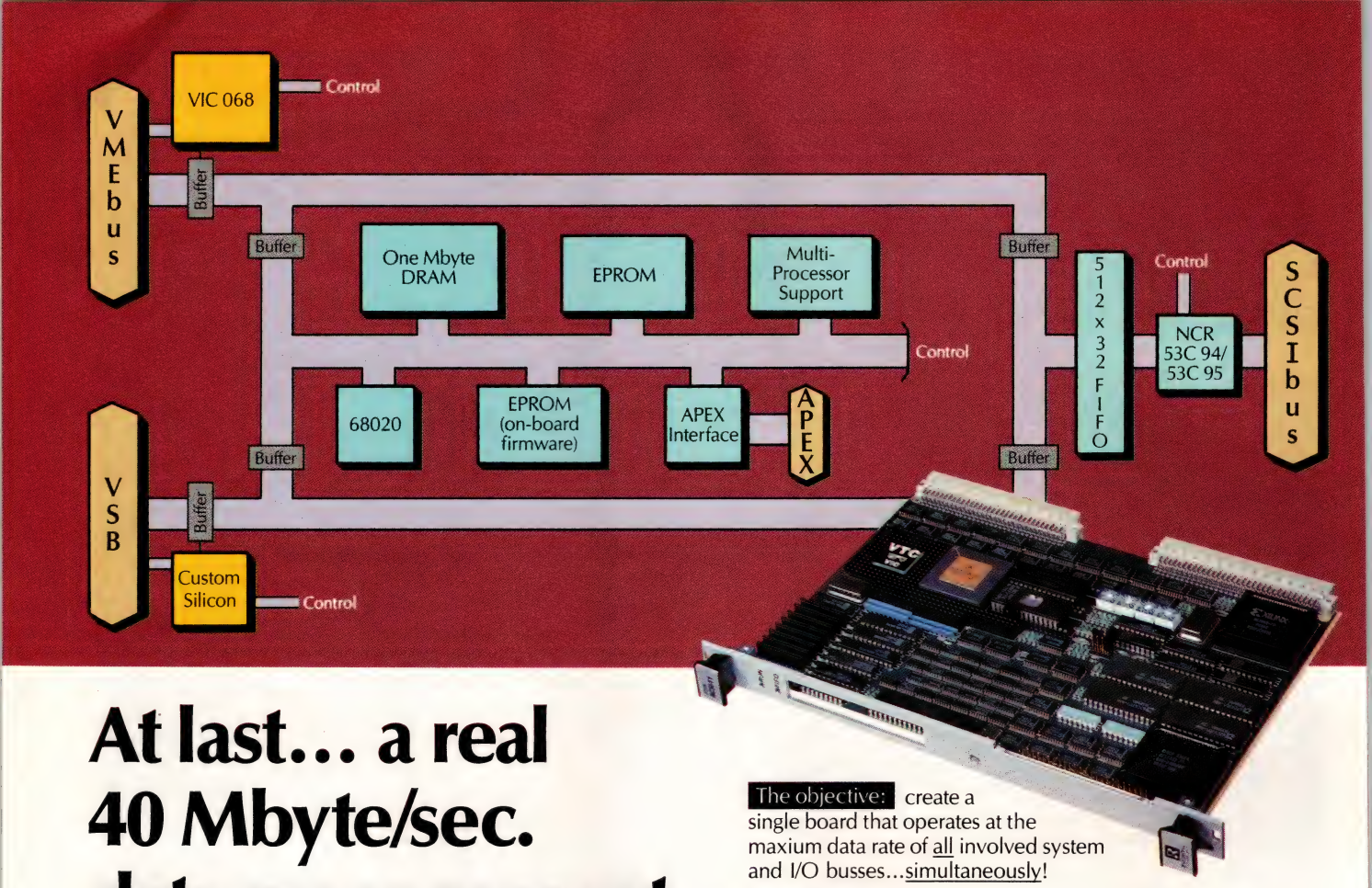
As the numbers in **Table 1** reveal, extensive switching capability is possible in a very small package. Mepcopal and Omron offer products that control as many as 16 signal lines in packages that require only 0.08 and 0.09 in.^{2} of pc-board space, respectively. These products can satisfy the most stringent packing-density needs. And as the **table** shows, even the largest package requires less than 0.5 in.^{2} of board area.

DIP-switch manufacturers are keeping up with the growing interest in surface-mount technology (SMT). More than half of the vendors listed in the **table** offer surface-mountable DIP switches. However, it's wise to use caution when you select a DIP switch for an SMT application (see **box,** "Taking the heat"). You should be especially careful if you're going to use an outside assembly service.

To increase board throughput figures in certain assembly operations (whether internal or external), solder-system oven temperatures can be set well above recommended specifications. Also, even in the best soldering system, temperature levels can vary from area to area across a pc board. If your switch happens to end up in a hot spot on a board, the plastic materials in the switch may become dimensionally



Compatible with automatic-insertion equipment, C&K's LD Series units come in 4-, 6-, and 8-position models and are available for either through-hole or surface-mount applications.



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With above-board profiles equivalent to those of standard IC packages, DIP switches no longer create air-flow shadowing problems.

unstable, especially if the switch vendor has merely reformed the leads of a standard DIP switch to get to market with a surface-mount device (SMD). Nevertheless, DIP switches can help you satisfy your design needs because they're built to handle harsh environments. In addition, you can choose from a wide variety of these switches.

Variety is the name of the game

The numbers in the **table** show that switch manufacturers do offer product diversity. With the exception of NKK's series of switches, all switch lines offer a wide choice of switch positions. Available actuator styles—such as rocker, piano key, or slide styles—aren't included. The rotary-type switches listed are available with shaft or screwdriver-slot actuators in top- or

Featuring a fully sealed construction, Omron's A6C switches are available in both side- and top-adjust versions. They also offer BCD or hexadecimal output codes.

Table 1 — Representative DIP switch parameters

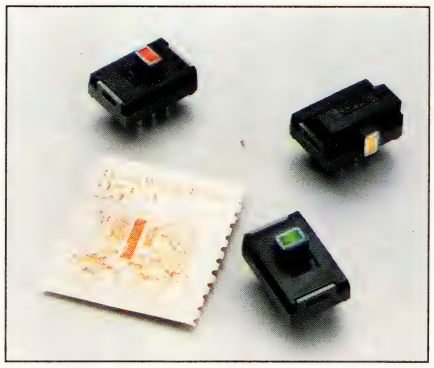
Manufacturer	Model number	Positions	Contact ratings mA/V dc	Operating range °C	Operating life operations	Seal	Surface maintable	Output code	Maximum mounting area in.²	Price
American Research & Engineering	K40	2 through 8	100/20	−40 to +100	2000	Tape	Yes	None	0.336	$0.65 (1000) for 8-position through-hole
AMP Inc	7100 series	2 through 10, 12	60/5 15/24	−17.8 to +87.8	2000	Tape	Yes	None	0.49	$0.55 (OEM qty) for 8-position unit
Augat/Alcoswitch	AD series	2 through 10	0.4 VA @ 20V dc	−30 to +85	5000	None	Yes	None	0.32	From $1.78 each
C&K Components Inc	LD series	4, 6, 8	100/5 25/25	−40 to +85	2000	Tape	Yes	None	0.248	From $0.58 (1000)
CTS Corp	Series 207	2 through 10, 12	50/6 2/0.05	−20 to +85	5000	Tape	No	None	0.390	$0.50 (5000)
EECO Inc	3300 series	10, 16	100/28	−40 to +85	10,000	O-ring	No	BCD, binary	0.334	$1.75 (5000)
Elma Electronic Inc	Series 07	10, 16	200/50	−40 to +85	10,000	O-ring	No	BCD, gray, hexadecimal	0.16	$3.50 (100)
Mepcopal Co	S-7000 series	10, 16	100/5	−40 to +85	10,000	O-ring	Yes	Hexadecimal, decimal	49 mm²	$2.00 (1000)
NKK Switches of America Inc	SS series	1	100/30	−10 to +60	10,000	None	No	None	0.22	$0.90 (100)
Omron Electronics Inc	A6C series	10, 16	100/30	−20 to +70	2000	O-ring	No	Hexadecimal, BCD	59.4 mm²	$2.10 (1000)
Siemens Components Inc	A3000 series	4, 5, 8, 10	5 VA	−25 to +85	5000	None	Yes	None	0.386	$1 (1000) for 8-position unit

Most rotary DIP switches are completely sealed and can handle almost any environment.

side-adjust versions.

Although many DIP switches are designed to switch logic-level currents and voltages, certain devices can switch hundreds of milliamps at voltage levels ranging to 50V. A number of manufacturers offer rotary-type DIP switches. These units greatly simplify switch-setting tasks. In fact, operators no longer need to have any knowledge of the binary number system; they simply rotate the actuator to the specified number, and everything is set. These rotary DIP switches also feature a variety of coded outputs, such as BCD-, binary-, Gray-, and hexadecimal-coded outputs.

Today's DIP switches can handle a wide range of applications and environments. For example, American Research and Grayhill offer switches that operate over −40 to +100°C, and almost all units handle 85°C environments. Even though these operating ranges don't qualify DIP switches for military applications, they certainly open up a wide range of application possibilities.



Available with either top or side actuators, NKK's SS Series slide switches require only a 0.22-in.^{2} mounting area and come with an LED actuator tip that lights up when the device is on.

All DIP switches are designed to withstand wave soldering and board cleaning. A tape seal is placed on the top of the switch to prevent any assembly-related contaminants from getting into the contact area. When the assembly operation is completed, you simply remove the tape.

For extremely harsh environments, you can turn to rotary-type DIP switches. These devices usually feature an epoxy seal on the bottom of the housing and an O-ring seal on the top of the housing. As

Taking the heat

Polymers are stiff and dimensionally stable below their transition temperature, but they get rubber-like above this temperature. The housing of standard, through-hole-type DIP switches is typically made of polybutylene terephalate, which has a glass-transition temperature of 200°C. Polyethersulfone material has a transition temperature of about 220°C and is a better choice than polybutylene terephalate, especially for machine-insertable DIP switches. In any case, either material can withstand wave soldering and cleaning operations.

Surface-mount applications are different, however. Surface-mount-assembly operations employ one of two soldering processes—vapor-phase solder reflow or IR convection. In the vapor-phase oven, a medium (usually Fluorinet) is heated to create a vapor over the medium. As the board moves through the oven, the vapor causes the solder to reflow. Vapor-phase systems typically operate at 218°C—a temperature that can effect the physical integrity of polyethersulfone material and reduce switch reliability. In addition, federal restrictions on the composition and use of fluorinated compounds have made the cost of the medium, and hence the assembly process, very expensive. Therefore, the IR-convection oven technique is a good alternative soldering process.

When run according to specifications, IR ovens also generate temperatures in the 220°C range—again too high for PES material. To solve the problems associated with board assembly, use materials made of liquid-crystal, wholly aromatic polyester polymers, which have a transition temperature in excess of 260°C.

Grayhill uses these materials for its Series 90H DIP switches, which are scheduled for introduction in February and March. These SMDs are available in 4-, 8-, and 10-position models. Contacts are rated to switch logic-level currents and voltages, and they have a 2000-cycle operating life. The switches are designed to operate over −40 to +100°C. An 8-position Series 90H switch costs $1.90 (100).

Although Grayhill believes that the use of liquid-crystal, wholly aromatic, polyester-polymer materials results in a more reliable product, the materials do have one drawback: cost. These materials cost about three times as much as polybutylene-terephalate materials. Switches made from these materials will naturally cost more than their through-hole-type counterparts, and these high prices won't decrease until the volume of surface-mountable DIP switches increases.

POWER BOOSTERS

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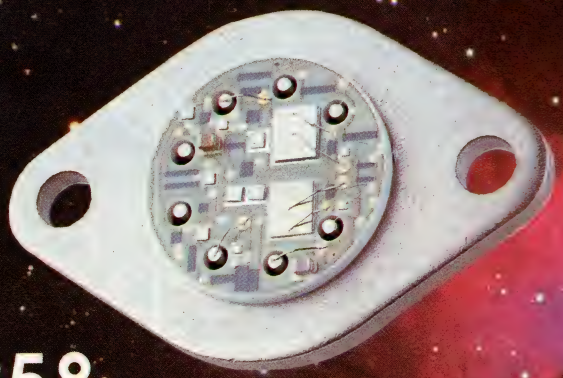

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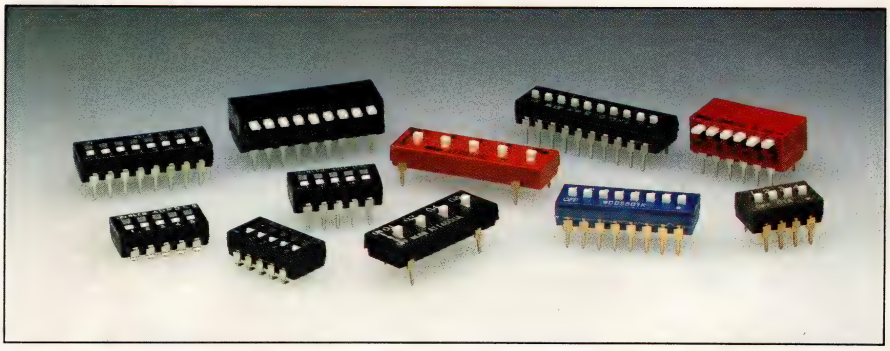
CIRCLE NO 57

The operating lifetimes of DIP switches aren't critical, because they're basically designed for set-and-forget services.

a result, they're totally sealed, and thus they can withstand the harshest environmental conditions.

American Research and CTS have taken special pains to improve switch reliability. The K40 line of devices from American Reasearch replaces a 25-piece assembly by using three simple components—two composite metal/plastic strips and one plastic-molded cover. Because it has fewer parts, there is less of a chance of component failure.

To increase the reliability of their Series 207 switches, CTS strove for novel contact design. For example, the switch contactors don't impinge on any plastic surfaces, which eliminates plastic abrasion and also protects contact surfaces from gold abrasion. Secondly, switch contactors don't deflect during actuation. The resulting constant contact pressure eliminates any contact overstressing. Finally, Series 207 switches have independent contactors and detents. This feature allowed CTS to optimize the design of the nondeflecting contactors and detents.



Featuring a gas-tight, high-pressure contact design that results in 240,000-psi force during actuation, Augat's AD Series switches can provide process compatibility without the use of tape seals.

What is the meaning of life?

When you're faced with the task of selecting a DIP switch, don't place too much emphasis on operating-life specifications. Basically, DIP switches evolved to satisfy set-and-forget services in applications such as memory addressing and coding, I/O-board operating conditions, and μP data entry. In such applications, dependable operation—the particular aim of today's DIP switches—is much more important than switch-cycle life.

Almost all the products listed in the **table** feature contacts that have precious-metal plating. In many cases, switch closure is based on a wiping-action scheme—a plus, considering that most units aren't environmentally sealed. To further enhance switch performance, CTS and American Research products feature bifurcated-type contacts. Finally, almost all of the products listed carry a 94V-0 UL rating.

EDN

For more information . . .

For more information on the DIP switches discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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Article Interest Quotient
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High 518 Medium 519 Low 520

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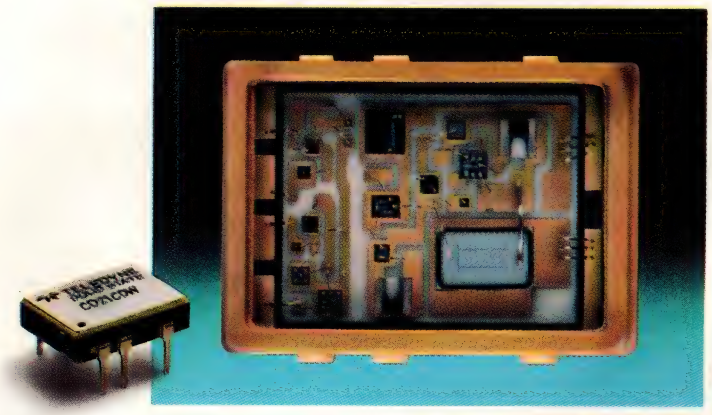


ACTUAL SIZE
CERAMIC PACKAGE

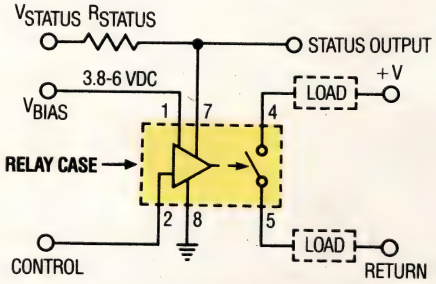
PART # CD21CDW

Review the electrical characteristics and call us for immediate application assistance.*

ELECTRICAL CHARACTERISTICS (–55°C to +105°C unless otherwise noted)				
	Min	Max	Units	
Bias Voltage (V_{BIAS})	3.8	6.0	V_{DC}	See Note 1
Bias Current (I_{BIAS})		15.0	mA	$V_{BIAS} = 5 V_{DC}$
Control Voltage (V_{IN})	0	18.0	V_{DC}	
Control Current (I_{IN})		250	µA	$V_{IN} = 5 V_{DC}$
Turn-Off Voltage $V_{IN\,(OFF)}$	3.2		V_{DC}	
Turn-On Voltage $V_{IN\,(ON)}$		0.3	V_{DC}	
Continuous Load Current		1.2	A	–55°C to +25°C
I_{LOAD} @ 60 VDC		0.7	A	+85°C
Output Trip Current (I_{TRIP})	2.4 (Typ.)		A	+25°C, 100ms
On-Resistance (R_{ON})		0.65	Ohms	
Turn-On Time (T_{ON})		1.5	ms	
Turn-Off Time (T_{OFF})		0.25	ms	
Status Voltage (V_{STATUS})	1	18	V_{DC}	
Status Current (I_{STATUS})		2	mA	$V_{SAT} \leq 0.3 V_{DC}$ See Note 2

Notes:
1. Series resistor is required for bias voltages above $6V_{DC}$. RS = $(V_{BIAS} - 6 V_{DC})/15$ mA
2. A pull up resistor is required for the status output. $R_{STATUS} = (V_{STATUS} - 0.3)/I_{STATUS}$
3. Output will drive loads connected to either terminal (sink or source).
4. Status circuit is a built-in test feature checking the input circuitry of the relay. Status output is low (on) when the input is on.

All power FET relays may drive loads connected to either positive or negative referenced power supply lines (source or sink modes).



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Teledyne Solid State, 12525 Daphne Avenue, Hawthorne, California 90250.

CIRCLE NO 59

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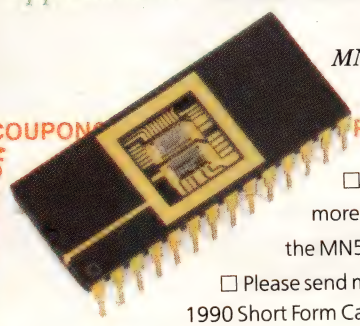

MN774

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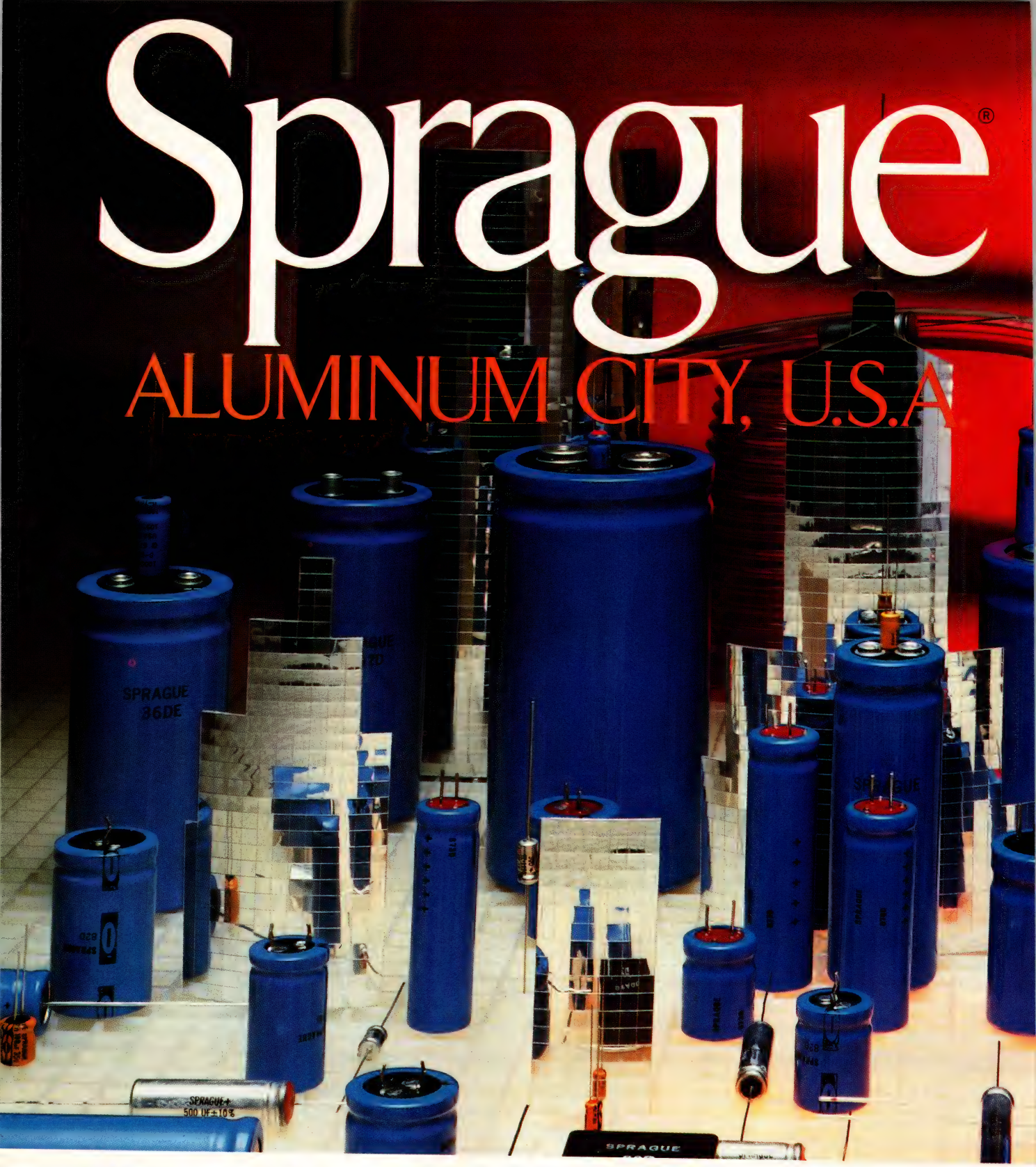

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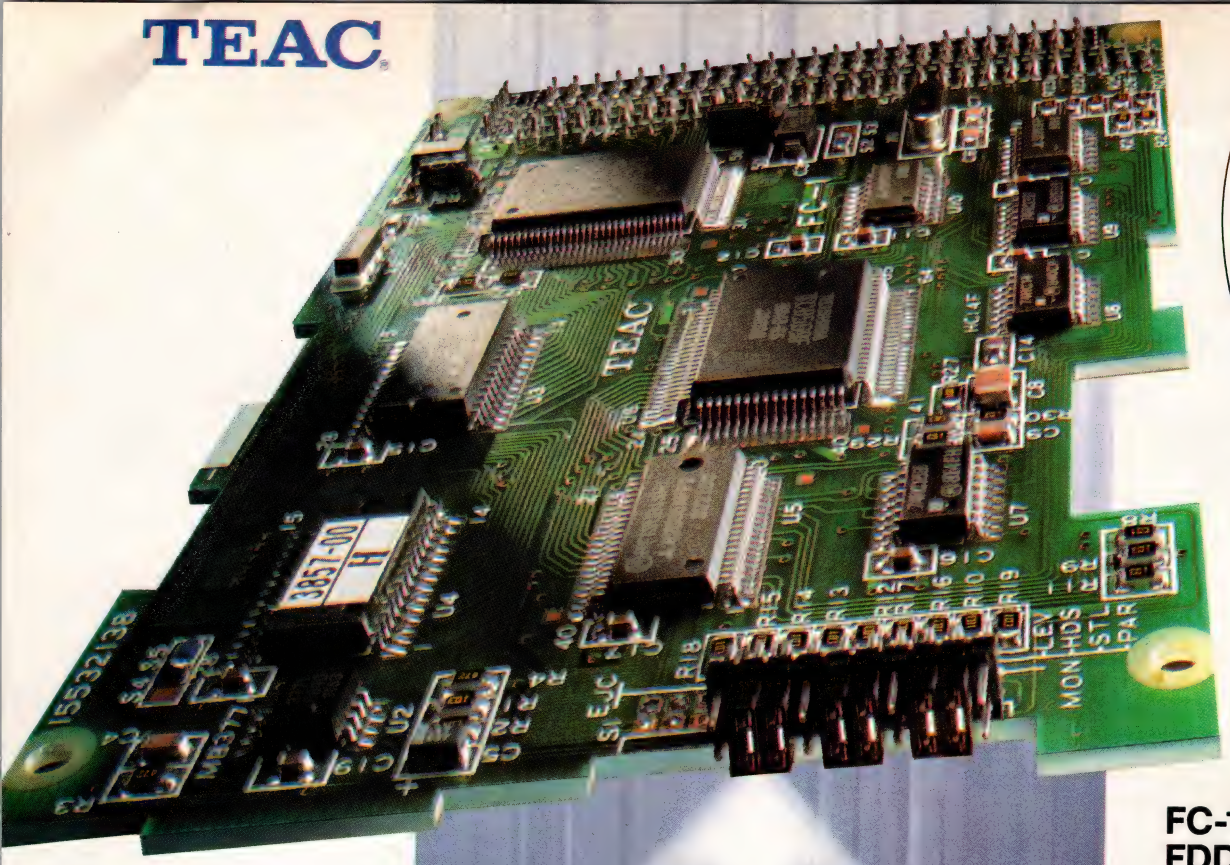

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FC-1
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Active filters feature −94-dB distortion and 100-dB dynamic range

The 680 Series high-performance fixed-frequency highpass and lowpass active filters feature low distortion, 100-dB-wide dynamic range, and a broad selection of transfer functions. Typical distortion is −94 dB at frequencies to 20 kHz, −88 dB above 20 kHz. Three lowpass, one constant-delay, and two highpass models are factory tuned to any user-specified corner frequency between 100 and 51.2 kHz ±2%.

The 8-pole Butterworth and Bessel lowpass filters exhibit a monotonic stopband gain roll-off at an ultimate rate of 160 dB/decade. The gain of the 8-pole Butterworth highpass filter increases at the same rate. The 8-pole, 6-zero elliptic lowpass filter's gain rolls off from the 0.03-dB passband edge to the 80-dB attenuation floor at 1.77 times the passband edge's corner frequency. The 8-pole, 6-zero constant-delay filter's 80-dB attenuation floor occurs at 3.57 times the 3-dB corner frequency. The 8-pole, 6-zero elliptic highpass filter features an ultimate gain rollup of greater than 90 dB/octave and an 86-dB attenuation floor.

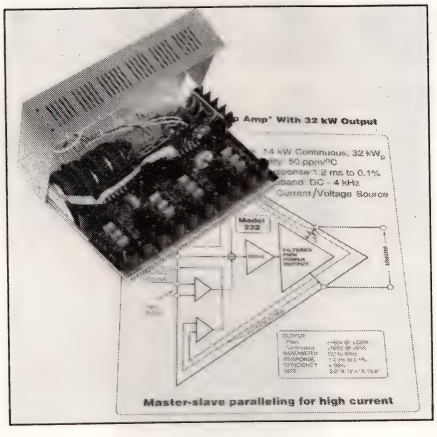
All models have a 20-kΩ input impedance (typ), a 10-Ω output resistance (max), and a noninverting gain of 0 to ±0.2 dB (lowpass) or 0 to ±0.5 dB (highpass) at 100 kHz. Over a 5-Hz to 50-kHz bandwidth, typical output noise is 50 μV for Butterworth, Bessel, and linear phase models, and 75 μV for all elliptic models. All of the filters, which cost $99, operate from ±15V power supplies over a 0 to 70°C temperature range and come in rugged 2×3×0.4-in. packages.

Frequency Devices Inc, 25 Locust St, Haverhill, MA 01830. Phone (508) 374-0761.

Circle No. 714

PWM power amplifier functions as an op amp or as a bipolar ac/dc supply

The Model 232-10 is a high-power, wideband PWM power amplifier with built-in feedback that enables it to function as a high-current op amp, as a programmable bipolar dc source with 50 ppm/°C temperature stability, as a programmable ac source from dc to 4 kHz, or as a power conditioner that delivers computer-shaped current or voltage pulses.

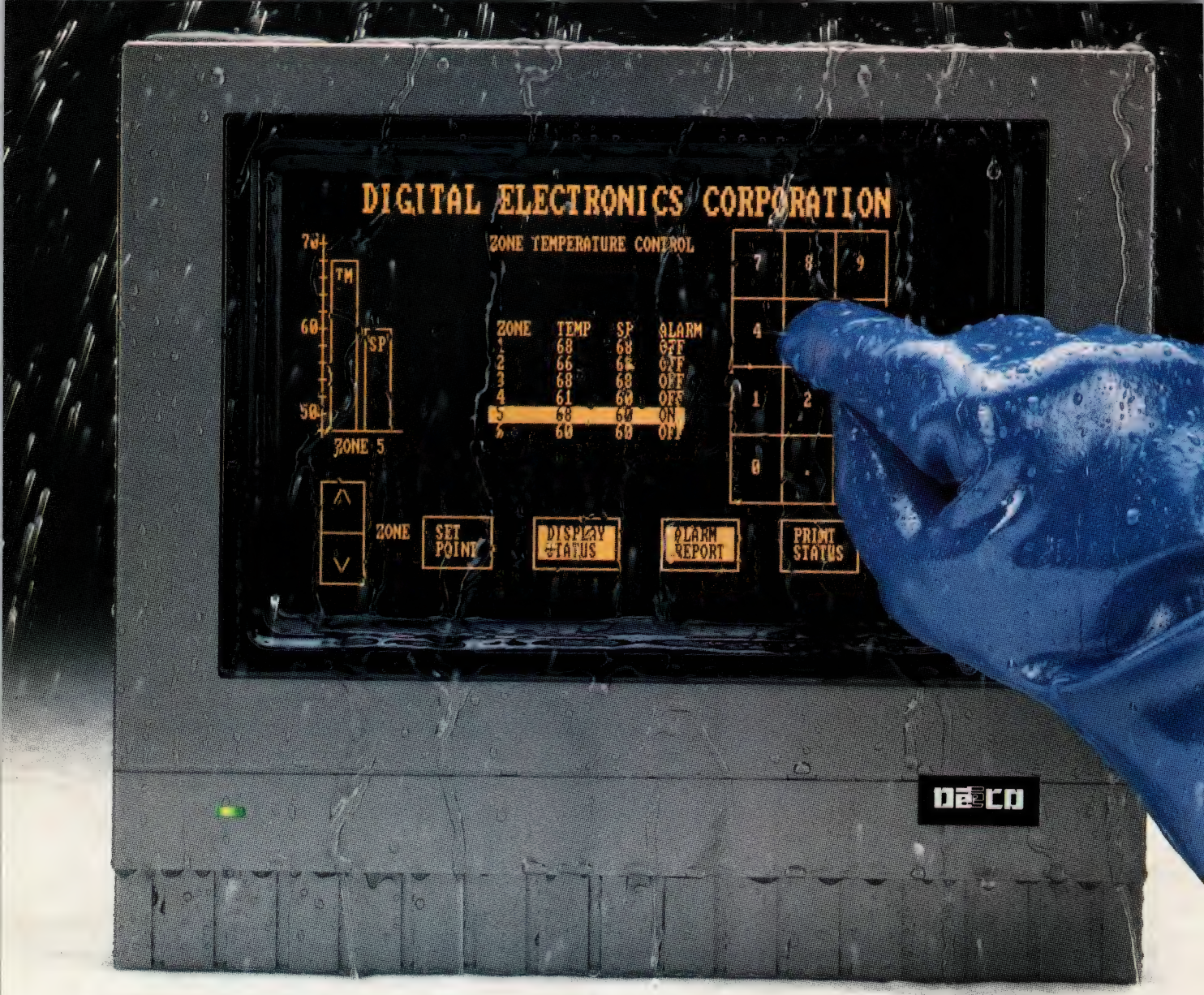


The unit provides a continuous output of ±160V at ±90A or a peak output of ±160V at ±200A. The amplifier provides 95% efficiency at full power and 0.2% THD for resistive loads at 200A and 200 Hz. You can parallel up to 20 of the 5.2×12.4×18.6-in. rack-mountable units to achieve a ±4000A output at ±160V. A MOSFET-bridge output circuit develops bipolar dc and wideband ac outputs from an unregulated single-polarity 60 to 160V dc supply.

The PWM circuitry operates at 81 kHz, enabling the unit to deliver current pulses that settle to within 0.1% of final value in 1.2 msec. The unit's 81-kHz switching frequency allows the manufacturer to build power filters into the unit; the filtering holds harmonic components of the switching frequency below 3 mA/L, where L is in mH. The amp also features overcurrent, overvoltage, undervoltage, and excessive-temperature protection. The $7500 unit dissipates 300W.

Copley Controls Corp, 375 Elliot St, Newton, MA 02164. Phone (617) 965-2410. FAX 617-965-7315.

Circle No. 715



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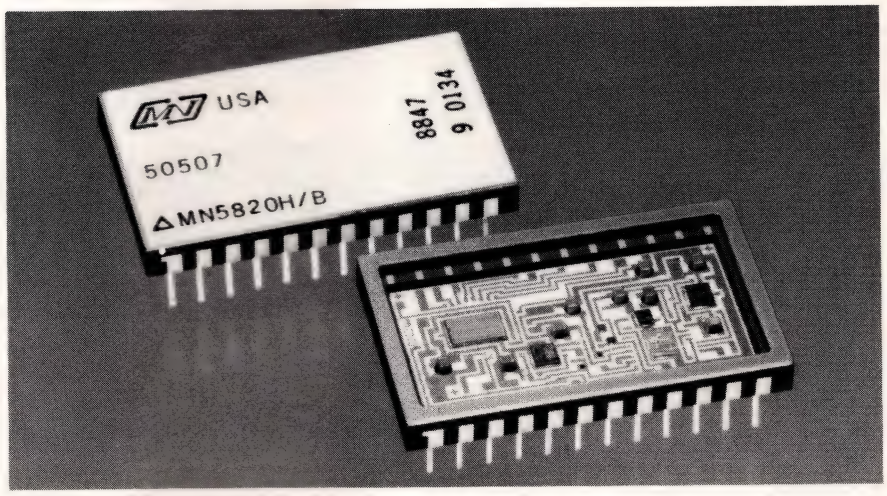
Digital Electronics Corporation, 31047 Genstar Road, Hayward, CA 94544-7831 (415) 471-4700

CIRCLE NO 64

8-bit 20-MHz flash ADC contains user-configurable support circuits

The MN5820 is an 8-bit, 20-MHz flash A/D converter that contains all necessary support circuitry in a single package. In addition, the support circuits are user configurable. The hybrid converter contains a bandgap voltage reference, voltage-reference top and bottom amplifiers, an analog input buffer amplifier and a 75-Ω input termination resistor.



The internal +1.2V bandgap reference is available on one of the device's pins so that you can use the reference along with the voltage-reference amplifiers. By connecting the pins in different combinations, you can configure the converter for input-voltage ranges of 0 to 1V, 0 to −1V, and ±1V. You can use the uncommitted input buffer amplifier to buffer the complex input impedance associated with flash converters. The internal 8-bit converter contains a 3-state output buffer and an over-range flag.

The converter's dynamic performance specifications include a minimum rms-signal to rms-noise ratio, excluding harmonics, of 41 dB with a full-scale input sine wave of 5 MHz. The harmonics and spurious noise with the same input frequency are a minimum of −42 dB. The device's maximum integral- and differential-linearity error is ±1 LSB. The converter is guaranteed to feature no missing codes over the complete temperature range. There are three ranges available: 0 to 70°C, −25 to 85°C, −55 to 125°C.

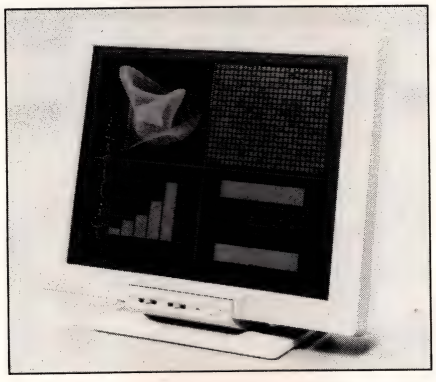
The converter runs off of ±5V, typically consumes 850 mW, and comes in a small hermetically sealed, 24-pin double-wide DIP; the converter costs $178.

Micro Networks, 324 Clark St, Worcester, MA 01606. Phone (508) 852-5400. **Circle No. 716**

Plasma display offers 1024×768-dot resolution

The FPF12000S is a 15-in.-diagonal, stand-alone plasma-display monitor with a 1024×768-dot resolution panel and an effective display area of 12.1×9.1 in. The entire monitor, including the circuitry and casing, has a ⅜-in.-thick profile and weighs approximately 4 lbs.

The monitor case has a keyboard-connection terminal, a power switch, an indicator lamp, and brightness- and volume-adjustment knobs. It also includes a 100V ac power supply. You can tilt the display forward 15° or backward 5° for easier viewing. Also, the casing design allows you to use the monitor as either a desktop or wall-mounted unit.



The panel display's neon orange-on-black display area contributes to its 20:1 contrast ratio. Panel brightness is rated at 5 cd/m^2, and you can clearly see screen images at a maximum viewing angle of 160°. The monitor costs $5000 and consumes 70W of power; it has a 50,000-hour MTBF rating.

Fujitsu Component of America Inc, 3330 Scott Blvd, Santa Clara, CA 95054. Phone (408) 562-1000. FAX 408-727-0355. **Circle No. 717**

A New VME Enclosure with Benefits That Really Stack Up:

40 Slot Capacity. Big systems in less space. In its maximum configuration, MaxChassis has *two* 20-slot VME card cages and two power supplies—two complete 20-slot VME systems in a single package only 14″ high, 26″ deep. One takes cards from the front, the other from the rear.

Match your needs exactly. There are 12, 20, and 32-slot systems, too. Tabletop or rack mount. The 12 and 20 slot models are only 20″ deep for VME or Multibus II, but you can get triple height (9U) cages and card depths to 400mm. There are three power supply choices from 400 to 800 Watts.

Ready to play. All MaxChassis come fully wired, complete with high-performance VME or Multibus backplanes. Just add your cards.

Disk drive modularity. The 12 and 32-slot models have slide-in peripheral mounting assemblies that hold up to four half-height drives. No brackets to design, no harnessing to make.

RFI tight. There's a front cover panel that holds RFI in (and out) so your system will be looked on approvingly by the FCC. The cover panel covers all those cables and connectors on the card fronts, so everyone else will look on your system approvingly, too.

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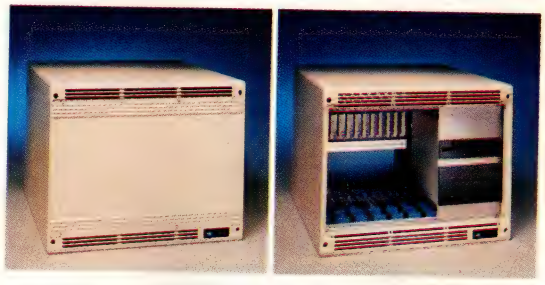

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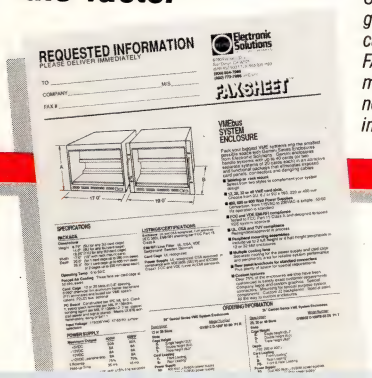

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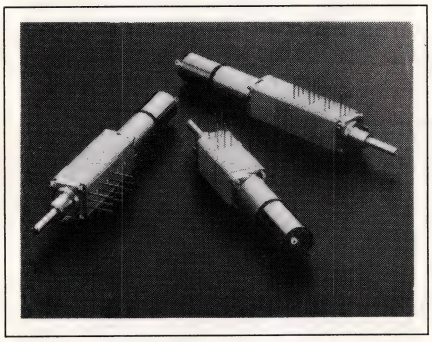
CIRCLE NO 65

Components



Miniature Motorized Potentiometer

The motorized potentiometer consists of an assembly of as many as four Series 388 or 389 potentiometer modules and a geared motor with a life expectancy that exceeds 1000 hours. The potentiometer sections are ½-in. square and the motor is ½-in. in diameter; their small size suits remote-control applications. A slip-clutch option allows you to manually override the motor to limit the mechanical rotation and manually adjust the potentiometer. The unit's effective rotation is $265 \pm 5°$; mechanical rotation is $295 \pm 5°$. Three different gear-motor styles are available: reduction ratio of 20:1 with 400 rpm for two controls; reduction ratio of 46.4:1 with 200 rpm for up to three controls; and reduction ratio of 104.4:1 with 100 rpm for up to four controls. The rpm ratings depend on the number of potentiometer sections in the assembly. The motors require a nominal supply voltage of 12V and operate from -30 to $+65$°C. From $100 (1000).

Clarostat Mfg Co Inc, Box 1507, Dover, NH 03820. Phone (603) 742-1120. FAX 603-742-0481.

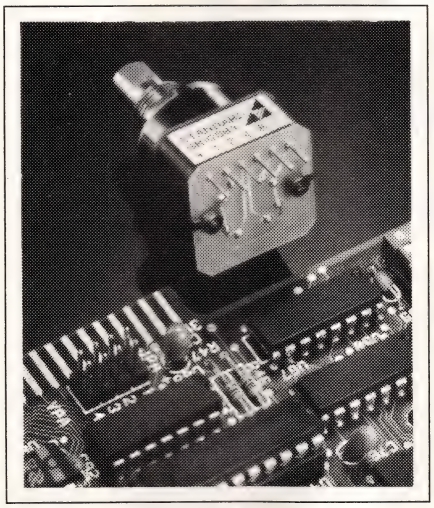
Circle No. 377

Sealed Pushbutton Switches

The GP Series of sealed pushbutton switches is available in both surface-mount and through-hole terminal styles. They are designed to withstand all soldering processes. Features include thermoplastic housings with a 94V-0 UL rating and internal O-ring actuator seals. The switches are available in spst and spdt versions. Straight, right-angle, and support-bracket terminal styles are offered with either 0.1- or 0.05-in. terminal spacings. Tin-lead terminal plating is standard. From $1.90 (1000).

C&K Components Inc, 15 Riverdale Ave, Newton, MA 02158. Phone (617) 964-6400.

Circle No. 378

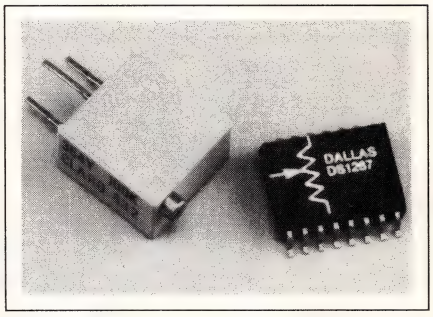


Optical Encoders

The SG-OE1 series of optical encoders features an interlock design, which prevents improper output codes by assuring perfect alignment of manufactured components. The devices' optical-switching technology eliminates metal contact and related metal fatigue. The rotary encode switch has a life rating of 1,000,000 cycles, and the life rating of the pushbutton encoder switch is 3,000,000 cycles. The encoders feature rotary actuation with or without a pushbutton option. You can select 16, 24, or 32 positions; shaft diameter; shaft length; and output codes. You can also request panel-sealed switches. Both binary- and gray-coded versions measure 0.767 in. $29.10 (100). Delivery four to six weeks.

Standard Grigsby Inc, 920 Rathbone Ave, Box 1528, Aurora, IL 60507. Phone (312) 844-4300. FAX 312-844-4286.

Circle No. 379



Dual Potentiometer

The DS1267 digital potentiometer contains two 256-position control elements that can be stacked for double precision, creating a dual potentiometer with 512 positions. You can also daisy-chain an unlimited number of potentiometers using only three signal wires. To set the equivalent of a wiper arm, the user writes an 8-bit word to an on-chip register. Because that number is stored in a read/write memory, you can read the settings electronically. A serial port provides the means for setting and reading the potentiometers. The device can switch from one setting to another directly—it doesn't increment through every setting. $4.60 (100).

Dallas Semiconductor, 4350 Beltwood Pkwy S, Dallas, TX 75244. Phone (214) 450-0400. FAX 214-450-0470. TWX 650-244-1669.

Circle No. 380

Piezoresistive Pressure Sensor

The Model 1431 is a solid-state, piezoresistive pressure sensor in a miniature, surface-mount package. The sensor measures 0.3×0.3 in., weighs 0.3g, and is available in absolute pressure ranges between 0

to 15 psi and 0 to 300 psi. The device operates from either a constant-current or constant-voltage supply and is accurate to better than ±0.25%. The typical full-scale output span of the sensor is 60 mV. Alternate packages are available for applications that require gage or differential-pressure measurements or other pressure ranges. This surface-mount sensor is compatible with automated assembly equipment. From $16 (sample qty); less than $2 (OEM qty).

IC Sensors, 1701 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1800. FAX 408-434-6687. **Circle No. 381**

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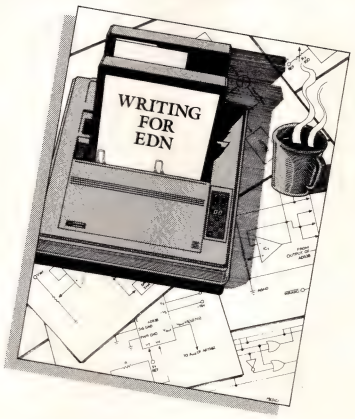

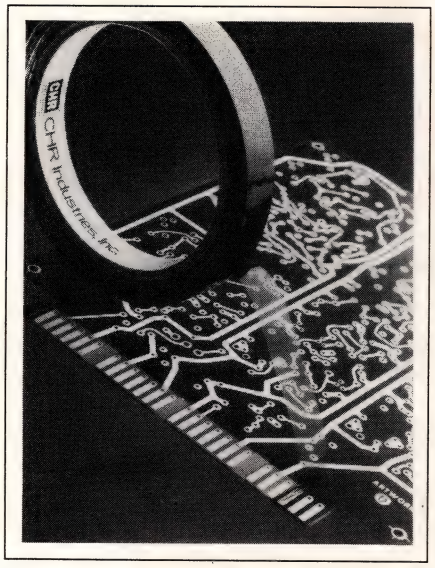

Protection Tape For pc Boards

Temp-R-Tape D926 protects the gold fingers of pc boards during wave soldering. The tape consists of 0.001 in. of Danar polyetherimide film and 0.0015 in. of silicone pressure-sensitive adhesive. Total tape thickness is 0.0025 in. The product endures high temperatures and is solvent resistant. The adhesion-to-steel rating of the product is 25 oz per inch of width. The tape is also nonflammable, nontoxic, and gold in color for high visibility. The length of each roll is 36 yards; 0.25-to 24-in. widths are available. 0.25-in. roll, $4.37.

CHR Industries Inc, 407 East St, New Haven, CT 06509. Phone (203) 777-3631. **Circle No. 382**

Ultrasonic Proximity Sensors

The 940 series of all-materials, ultrasonic sensors can detect any metal, glass, plastic, liquid, or solid target within ±2 mm or ±5% of the target-to-sensor distance. The sensing distance for the devices is 800 mm (max). The sensors are 30 mm in diameter and come in a stainless steel housing. An integral, three-turn potentiometer enables you to fine-adjust the digital setpoint between 100 and 800 mm from

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CMOS

Part number	GESMPU-18A	GESSBS-8	GESSBS-8L
Processor	i80286	i80186	i80C186
Speed	10 MHz	16 MHz	16 MHz
Coprocessor	80287 (Optional)	80187 (Optional)	80C187 (Optional)
# of socket	2	4	4
ROM capacity	256K	512K	512K
ROM supplied	0	0	0
RAM capacity	512K	512K	512K
RAM supplied	512K DRAM	256K SRAM	256K SRAM
# Serial ports	2 RS232	2 RS232	2 RS232
# Parallel I/O	0	24 TTL	24 TTL
# Timers/# Bits	3 x 16-bit	3 x 16-bit	3 x 16-bit
Clock/Calendar	Yes	Yes	Yes
Battery	Yes	Yes	Yes
Ext. addressing	16 MB	1 MB (1)	1 MB (1)
Power @ 5V	2.1A	1.4A	200mA
Power @ ± 12V	20mA	20mA	20mA
Other features	51-bit CMOS RAM	iSBC 186/03 Similar (2)	All CMOS Design

(1) Minus on-board memory (2) Intel Multibus 1 Single Board Computer

PS: i80386 is coming soon. Call for details.

Gespac

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Fax. (602) 962-5750

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83500 La Seyne
France
Tel. 94 30 34 34
Fax. 94 87 35 52

INTERNATIONAL
18, Chemin des Aulx
CH-1228 Geneva
Switzerland
Tel. (022) 794 3400
Fax. (022) 794 6477

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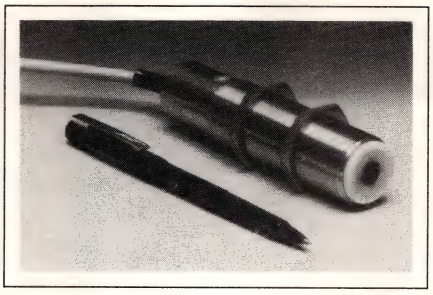
the sensor. An LED alignment/echo sound-wave-strength indicator simplifies installation. A transmit-inhibit feature allows you to multiplex several sensors. The devices have built-in protection against overload, power-input reverse polarity, transients on supply and signal leads, and short circuits. The output options are normally open, current-sinking npn transistors or current-sourcing pnp transistors. From $195.



Micro Switch, 11 W Spring St, Freeport, IL 61032. Phone (815) 235-6600. **Circle No. 383**

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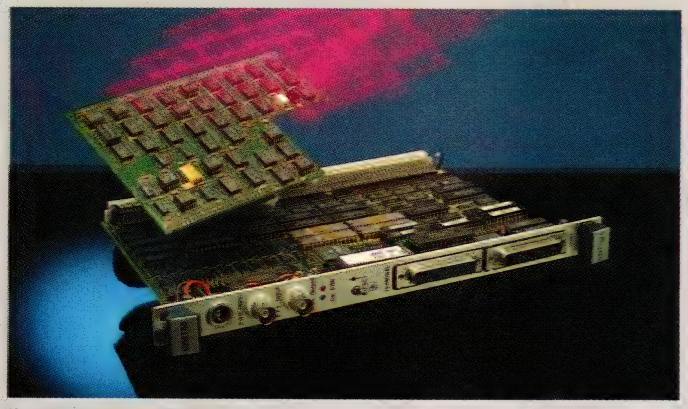

The VBT-321 Advanced VMEbus Analyzer concept has now been expanded with the new VBAT-321-Piggyback module that automatically screens for violations of the VME specification.

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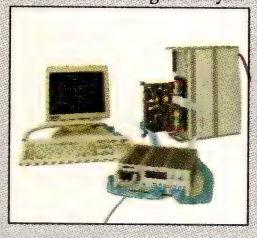
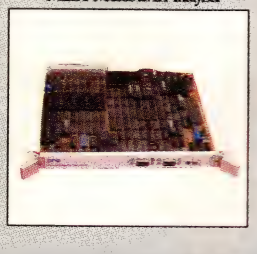
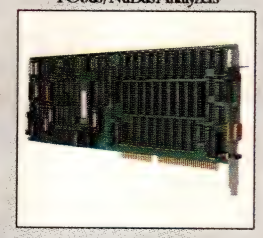
PMA-030 680xx Program Analyzer



M2BT Multibus II Analyzer



PC bus/NuBus Analyzers



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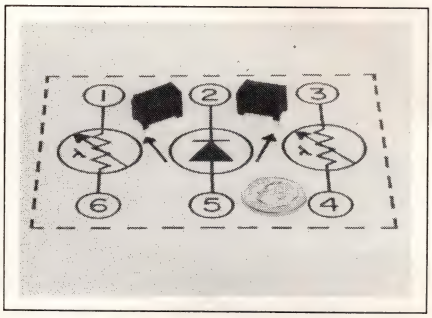
CIRCLE NO 5



Dual Optoisolators With Isolated Outputs

The CLM 400D and CLM 410D series of optoisolators each incorporate one LED with two photoconductive cells to provide dual optoisolators with isolated outputs. The units' isolation rating is 2000V. The dual, isolated outputs permit you to use one of the sensors in a feedback configuration to control the drive current to the LED. The 400D series has an on-resistance of 6 kΩ with 1 mA of drive current, and 600Ω with 20 mA of drive current. The 410D series features on-resistances of 850Ω with 1 mA of drive current, and 250Ω with 20 mA of drive current. The units are rated at 25°C, but you must derate the power rating to 0 at 75°C. $2.80 (1000)

Clairex Electronics, 560 S Third Ave, Mt Vernon, NY 10550. Phone (914) 664-6602. **Circle No. 384**

Temperature-Compensated Crystal Oscillators

The CO-253 series of temperature-compensated crystal oscillators features frequency stability of $\pm 2 \times 10^{-7}$ over the 0 to 50°C temperature range, and $\pm 1 \times 10^{-6}$ over the −55 to +85°C temperature range, in a 24-pin DIP package. The

IBM PC Data Acquisition Highlights. **No. 2 in a series.**

	MODEL	DESCRIPTION	ANALOG INPUTS Channels	Resolution (bits)	DIGITAL FUNCTIONS	SCREW TERMINAL PANELS	PRICE
LOW COST	DT2811-PGH	Low Cost A/D, D/A, Interrupt	16SE/8DI	12			95
	DT2811-PGL	Low Cost, Low-Level A/D, D/A; Interrupt	16SE/8DI	12			395
	DT2814	Low Cost A/D, Int.	16SE	12			575
	DT2815	Low Cost D/A	—	—			239
	DT2817	Low Cost DIO	—	—			nsult ctory
	DT2819	Am2935A Counter/ Timer, DIO	—	—			595
GENERAL PURPOSE	DT2808	Low Cost, DMA	16SE	10			995
	DT2801	General Purpose, DMA	16SE/8DI	12			$1,095
	DT2801-A	Higher Throughput, DMA	16SE/8DI	12			$1,970
	DT2801/5716A	High Resolution, DMA	8DI	16			$1,095
	DT2805	Low Level, DMA	8DI	12			$2,070
	DT2805/5716A	Low Level, DMA	8DI	16			$2,495
	DT2809	16-bit SS&H, DMA	8SE,SS&H	16			$1,895
	DT2818	SS&H, DMA	4SE,SS&H	12			$1,095
HIGH SPEED	DT2824-PGH DT2824-PGL	High Throughput, Low Cost A/D; DMA, Ints.	16SE/8DI	12			$1,345
	DT2821	High Throughput, DMA,	16SE/8DI	12			$1,995
	DT2821-F-16SE, DT2821-F-8DI	Very High Throughput, DMA, Interrupts	16SE or 8DI	12			$2,995
	DT2821-G-16SE, DT2821-G-8DI	Ultra High Throughput, DMA, Interrupts	16SE or 8DI	12			$2,895
	DT2823	High Res., DMA, Ints.	4DI	16			$1,545
	DT2825	Low Level, DMA, Ints.	16SE/8DI	16			$2,595
	DT2827	High Resolution, DMA	4DI	16			$2,195
	DT2828	High Throughput, SS&H, DMA, Interrupts	4SE, SS&H	12			$2,995
	DT2829	16-bit SS&H, DMA, Int.	8SE,SS&H	16			$1,450
DT-Connect™	DT2841	40kHz, DT-Connect™	16SE/8DI	12			$2,095
	DT2841-F-16SE, DT2841-F-8DI	150kHz, DT-Connect™	16SE or 8DI	12			$2,695
	DT2841-G-16SE, DT2841-G-8DI	250kHz, DT-Connect™	16SE or 8DI	12			$2,995
	DT2841-L	750kHz, DT-Connect™	4DI	12			$2,495
	DT2847	16-bit, DT-Connect™	4DI	16			$2,095
	DT2848	SS&H, DT-Connect™	4SE	12			
FLEXIBLE I/O	DT2806	iSBX A/D	Up to 80SE/40DI	12	24	60(-T)	$ 375 to $2,140

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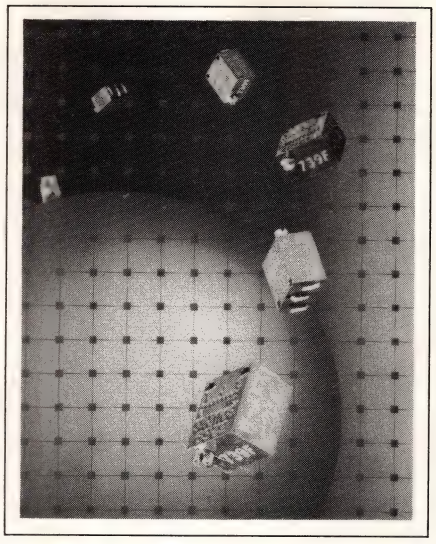
crystals' aging rate is 1×10^6/year. The device's output is HCMOS/TTL compatible at any frequency in the 5- to 50-MHz range. Standard supply requirements are 15 and 5V, but a single 5V option is available. The resistance-welded packages measure $0.8 \times 1.4 \times 0.39$ in. The crystals achieve this small size through internal surface-mount construction on a ceramic substrate. $333 (10).

Vectron Laboratories Inc, 166 Glover Ave, Norwalk, CT 06850. Phone (203) 853-4433. FAX 203-849-1423. **Circle No. 385**



Multiturn Trimmer

Measuring 0.25 in. square, the Model 3269 multiturn trimmer is approved per DESC drawing 88040 and meets MIL-R-22097 specifications for nonwirewound variable resistors. The unit is compatible with all popular surface-mount soldering processes. In addition, it is sealed to meet the requirements of high-pressure aqueous cleaning techniques. Standard resistance values range from 10Ω to 1 MΩ. Resistance tolerance is 10%, and resistance contact variation is 3%. The trimmer also features a 250-mW power rating, a 100-ppm/°C temperature coefficient, and a −65 to +150°C operating range. It's available in top- and side-adjust styles. From $1.98 (1000). Delivery, 10 weeks ARO.

Bourns Inc, 1200 Columbia Ave, Riverside, CA 92507. Phone (714) 781-5500. TLX 676423.

Circle No. 386

Abort Timer

Model 328 modem abort timer connects between modem and computer ports. It monitors the communications interchange and disconnects the hookup when it detects zero data flow. The timer features a switch-selectable 1- through 16-minute timed interval from initial dial-up to modem abort. It determines whether there has been a transmit data (TD) or a receive data (RD) signal during the timed inter-

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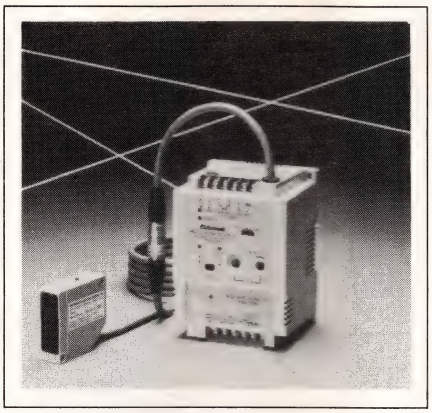
val. If it detects no TD or RD signal during the timed interval, the 328 drives the data carrier detect (DCD) signal low for 5 sec. In turn, the host releases the line, freeing the modem to receive new incoming calls. The unit supports synchronous and asynchronous communications and is transparent to full-duplex data and protocol signals. The module comes with male and female DB25 connectors to ease termination procedures. $87.

Telebyte Technology Inc, 270 E Pulaski Rd, Greenlawn, NY 11740. Phone (516) 423-3232. FAX 516-385-8184. **Circle No. 387**

Optical Sensors

The MQ-LA photoelectric sensors combine laser and triple-beam technologies to develop a measurement system that features detection resolutions as low as 0.001 in. They offer



both analog (±5V) and digital outputs—either relay or transistor. The two models offer different set-point-detection capabilities—1 to 2 in. (LA40) or 2 to 4 in. (LA75). The sensors are available for either panel or DIN-rail mounting. $975 (50).

Aromat Corp, Industrial Products Div, 629 Central Ave, New Providence, NJ 07974. Phone (201) 464-3550. **Circle No. 388**

Surface-Mountable Reed Relay

The 9200 Series surface-mountable reed relay uses an automated process to solder the relay's components to the lead frame, thus producing high-quality electrical connections. A coaxial shield provides a characteristic impedance of 50 to 75Ω. The 9200 relay design provides approximately 1.4 pF of capacitance from the open reed to where the shield and coil are tied together. An automated, computerized life and parametric test system tests and specifies each relay for user-specified loads. The relays are available in a rugged, thermoset epoxy package for auto-insertion in axial, radial, gull-wind, and J-terminal configurations. The package provides more than $10^{13}\Omega$ of isolation resistance. The manufacturer provides electrical specifications, time-domain-reflectometry data, dielectric-absorp-

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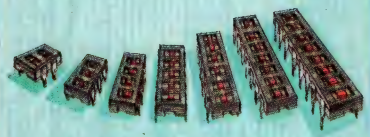
CIRCLE NO 6

SURFACE MOUNT DIP SWITCH

SURFACE MOUNT

"J" OR GULL WING

2 TO 8 POSITION



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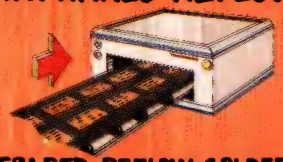

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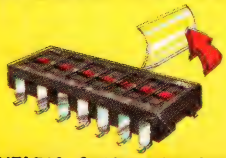

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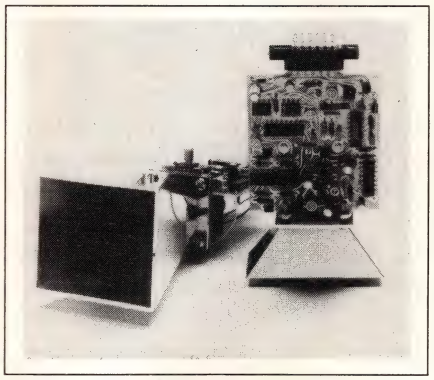

Motion-Sensor Evaluation Kit

The MSM 10200 microwave, noncontact, motion-sensor evaluation kit is furnished with two horn antennas. The broad-beam antenna has a sensing range of 50 ft max and is suited for large targets. The narrow-beam unit is useful for small objects and has a 150-ft max sensing range. A sensing module, which operates in a transmit/receive mode, an application note on sensor interfacing, and pc-board-mountable signal-conditioning electronics complete the kit. The sensor module meets FCC regulations for frequency, output power, stability, and emissions. It operates from 10 to 26V dc inputs and draws only 10 mA. The signal-conditioning circuitry contains the power supply, amplifiers, comparator, and an output switch, which drives the oscillator and converts the detected output to either a switch closure output or an analog output. $195.

Alpha Industries, 20 Sylvan Rd, Woburn, MA 01801. Phone (617) 935-5150. FAX 617-935-4939.

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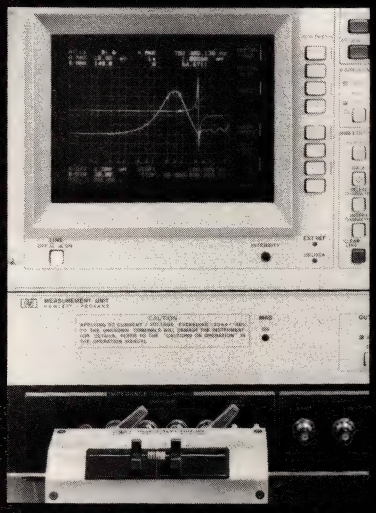

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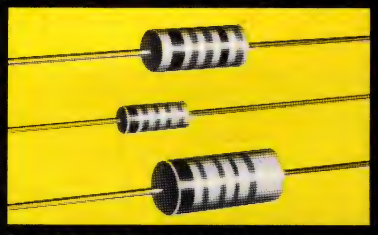

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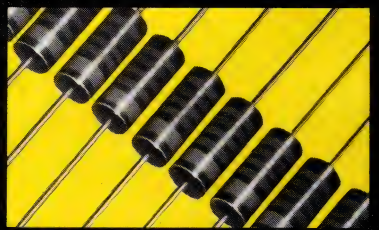

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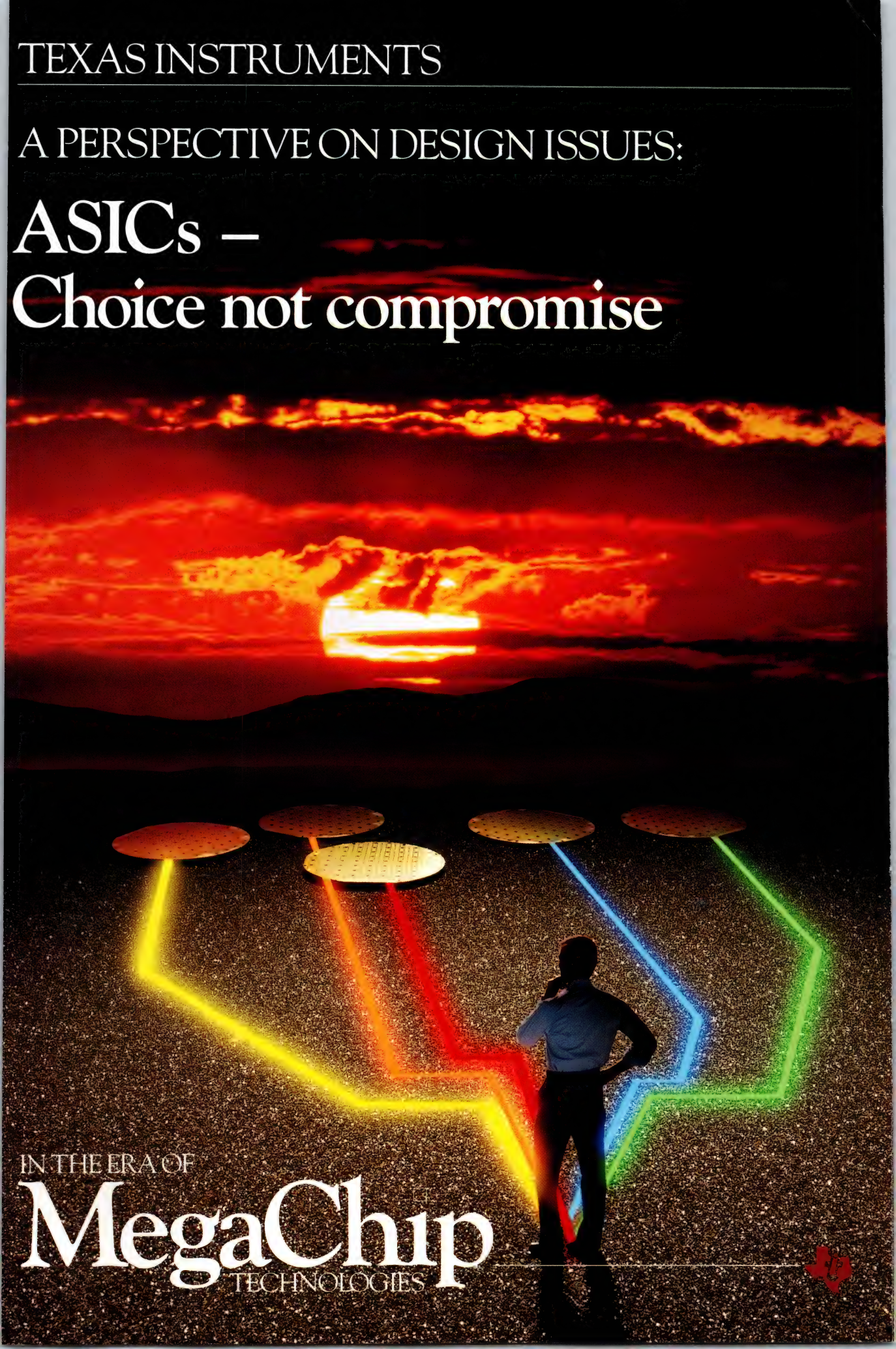
ASICs – Choice not compromise



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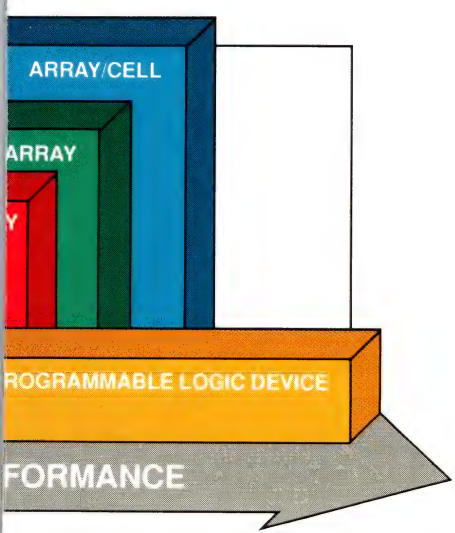
Thus, you can tailor a standard-cell design to meet your exact system requirements. As with our gate arrays, a design kit is available, as well as technical design assistance through TI's ASIC design centers.

For details about the support and service TI offers, please turn the page.

T SPECTRUM



"I need a high-speed part with unique functionality. Standard architecture is a big priority, too. Plus, I'm going into production and need volume delivery now."

The TI Solution:

Programmable Logic Devices

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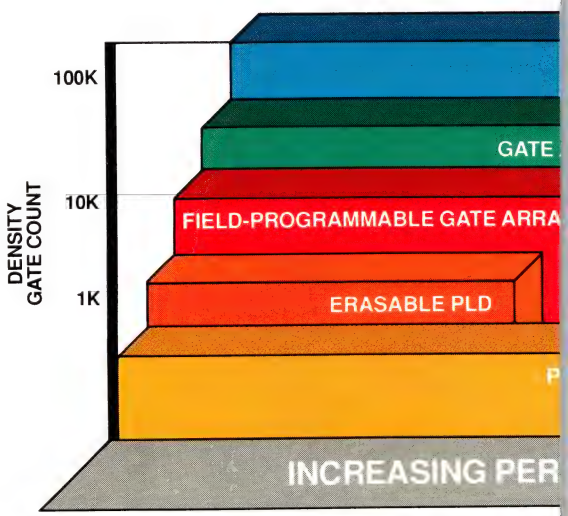
TI's ASIC PRODUCT



"At Texas Instruments, you have the choices you need to get the ASIC you need. That's the difference between an ASIC device and an ASIC solution."

"An ASIC solution is more than a choice of silicon. To keep you from compromising on a square peg for a round hole, an ASIC solution involves many considerations: Your performance needs. How much control you want to exercise. The amount of support you require. What you can spend. How narrow your market window is. It's the result of you and your supplier weighing all the choices and reaching a balanced decision. At Texas Instruments, that's the way we like to work.

"A solution should not limit you to 'classic' ASICs — gate arrays and standard cells. That's why TI includes user programmables in its ASIC lineup. We manufacture high-performance, programmable logic devices (PLDs) and high-density, field-programmable gate arrays (FPGAs).

"Such a broad choice allows you to make better value judgments about control, NRE investment, and cycle times.

"TI advocates open-system CAD architectures instead of confining you to proprietary CAD systems. We support both PC- and workstation-based design systems.

"We provide as much advice and counsel as you need or want just about anywhere in the world. Our documentation is so comprehensive it can fill your bookcase as it fills your needs.

"We are looking to future solutions. For example, we are developing submicron CMOS and BiCMOS gate arrays and standard cells with densities over 100K gates. We are extending our support by developing software that migrates FPGA designs to mask-programmed gate arrays.

"An ASIC solution also brings with it assurances of the supplier's dependability, stability, and capability to produce and deliver.

"At TI, we invite you to experience the difference between compromise and choice — the difference between an ASIC device and an ASIC solution."

Walden C. Rhines, Ph.D.
Executive Vice President, Semiconductor Group
Texas Instruments Incorporated

"On my schedule, livery delays and necessary risks are t. Our design quires the density of ate array, but we ed to handle all the ogrammation rselves."

e TI Solution:
ield-Programmable Gate Arrays

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The TI Solution:
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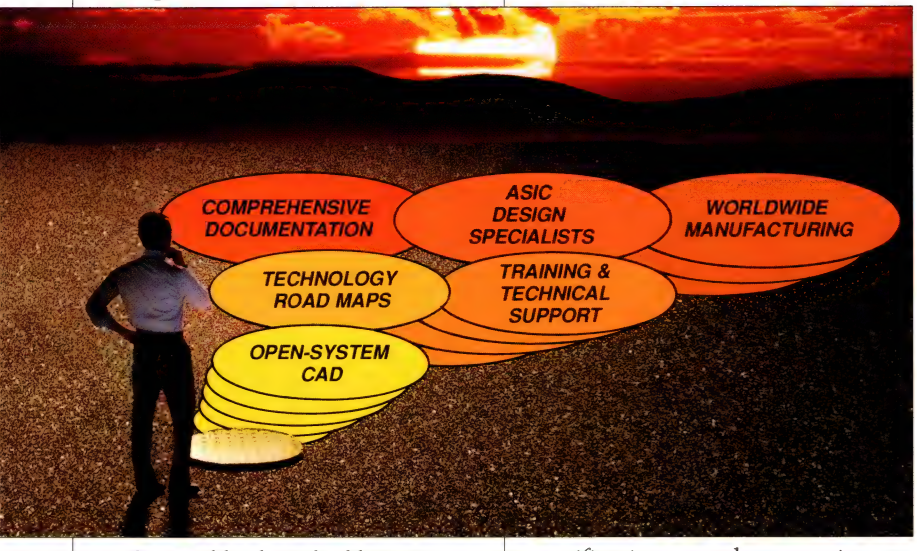
Our design flow is straightforward and minimizes the possibility of surprises.



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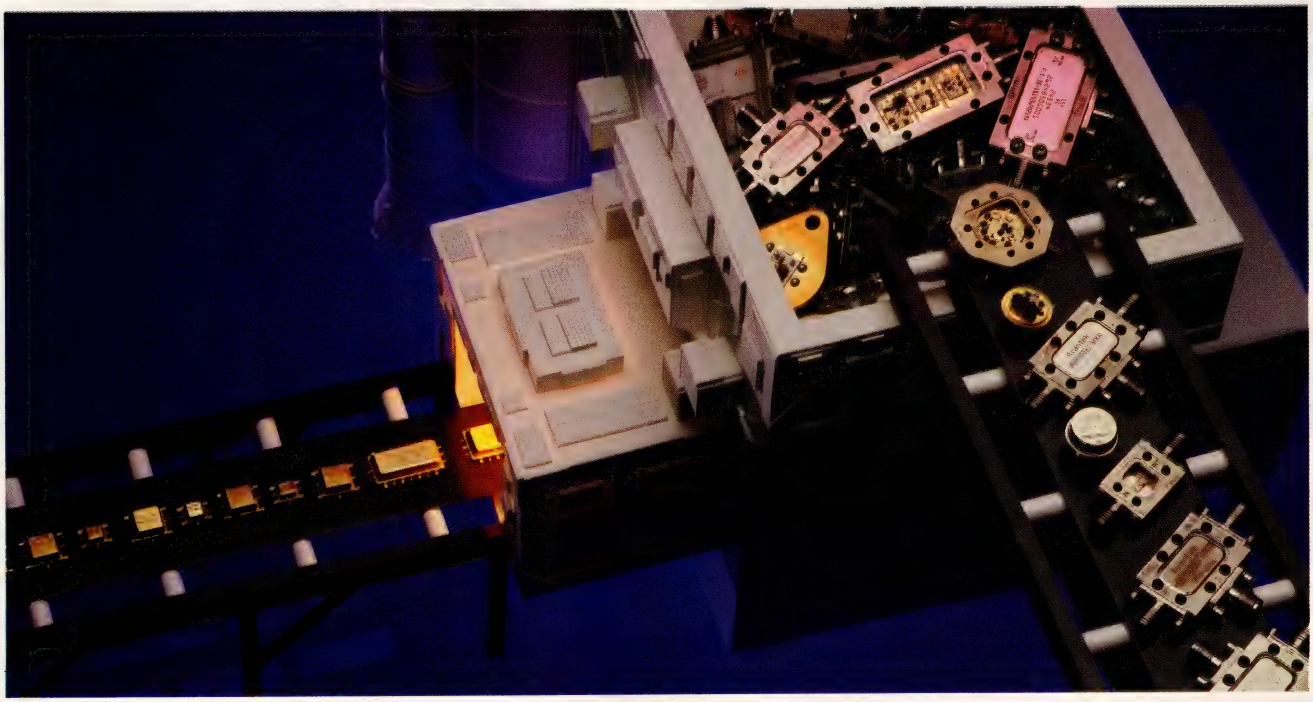

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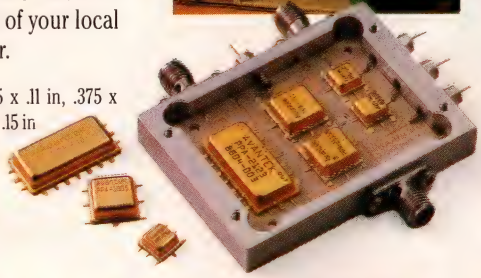

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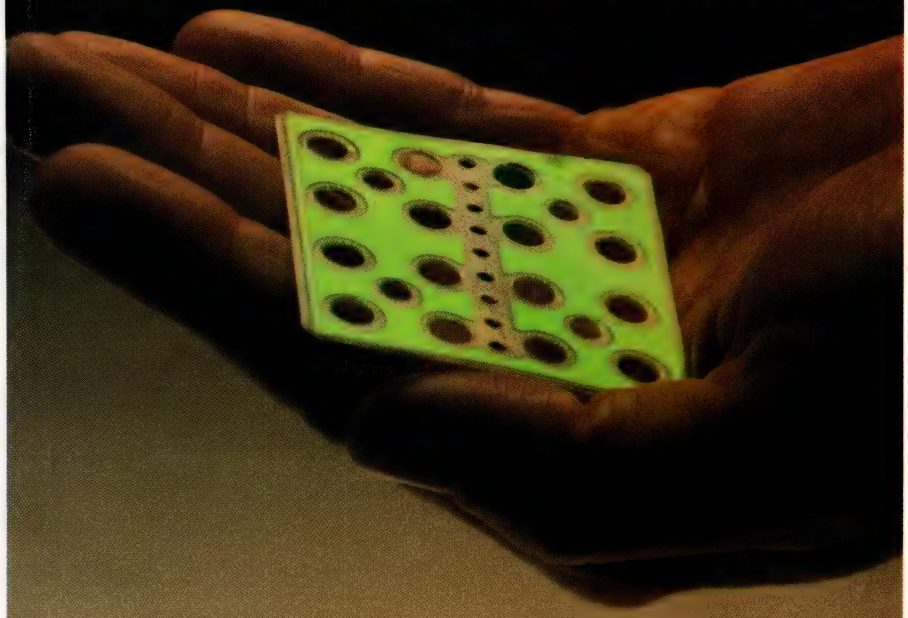

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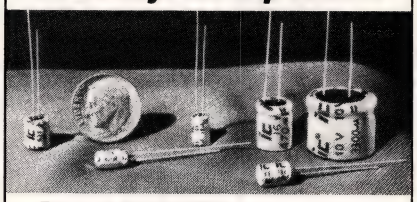

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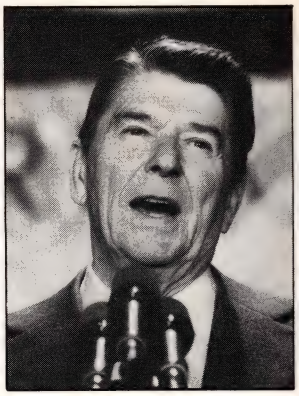
CIRCLE NO 4

In 1979, Margaret Thatcher is voted in as Prime Minister of Great Britain...

and EDN is voted #1 in readership.

In 1980, Ronald Reagan is elected President of the United States...

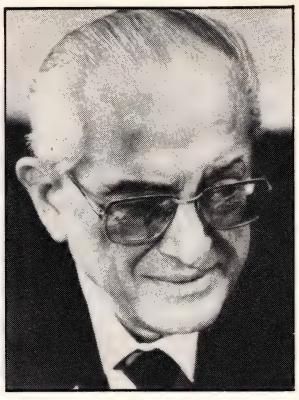


and EDN presides as #1 in readership.

In 1981, Sandra Day O'Connor is the 1st woman on the Supreme Court...

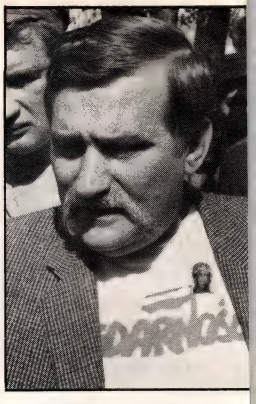
and EDN is first in readership.

In 1982, Yuri Andropov is elected as the leader of the USSR...



and EDN leads as #1 in readership.

In 1983 Lech Walesa of Poland wins the Nobel Peace Prize...



and EDN wins the #1 prize in readership.

WORLD

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Winning one study doesn't make history. But winning 84% of 177 independent readership studies since 1978 makes EDN a first class world leader. That's more wins than the rest of the electronics publications combined.

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	EDN	Electronics
Zenith Electronics	#1	5
Sprague Semiconductor	#1	5
SGS Thomson Semiconductor	#1	5
3M	#1	5
Apex Technology	#1	5
Sipex Corporation	#1	4
Kyocera Northwest, Inc.	#1	NOT INCL.

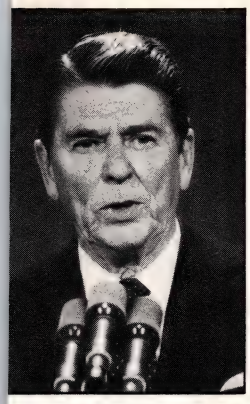
CUMULATIVE WINS—
% of Readership/Reader Preference Wins* 1978–1989 (to date)

177 studies/256 questions

Percentages add to more than 100% due to ties

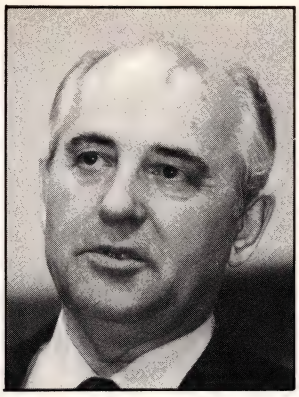
*Independent studies are conducted across customer/prospects lists or TIDS lists, not across a magazine's or newspaper's own list, which results in obvious bias. **Results based on the question

1984, Ronald Reagan
e-elected #1 in a
dslide...



d EDN is re-elected #1
a readership landslide.

In 1985, Mikhail Gorbachev is elected as the leader of the USSR...



and EDN is elected the leader in readership.

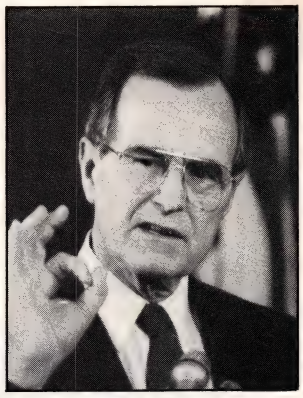
In 1986, Corazon Aquino is chosen as the President of the Philippines...

and EDN is chosen as #1 in readership.

In 1987, Margaret Thatcher wins a third term as Prime Minister...

and EDN wins another year as the leader in readership.

In 1988, George Bush is elected to highest office in the United States...



and EDN holds the #1 spot in readership.

.EADERS

But In The World Of Covering Electronics Technology, And EDN's Leadership In Readership Reign Continues.

eadership/reader preference study wins:

Electronic Design	Electronic Products	EE Times	Electronic News
2	4	3	NOT INCL.
2	4	3	NOT INCL.
4	3	2	NOT INCL.
2	4	3	6
2	3	4	NOT INCL.
2	NOT INCL.	3	NOT INCL.
3	2	4	5

84%

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And only a leader dares to offer $1000 to anyone who can disprove its claim to readership. No other electronic engineering magazine or newspaper in the US or throughout the world has won more independent readership/reader preference studies than EDN.

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Cut through the confusion surrounding high-performance DSOs

As DSO manufacturers struggle for ever-higher bandwidths, sample rates, resolutions, and processing features, they are also trying to come up with the right blend of these features at the right price.

Doug Conner,
Regional Editor

High-performance digital storage oscilloscopes (DSOs), which are defined in this article as DSOs with bandwidths of 300 MHz and over, have been available for several years, yet they are still in their infancy and evolving rapidly. Understanding the features of different DSOs and how those features suit your applications can be difficult. The fine print in the specifications is important, but sometimes not all the information is there.

The key specifications in a DSO are bandwidth, sample rate, resolution, record length, and waveform processing. These specs are intertwined and difficult to sort out—sometimes because of the lack of accepted standards, but often because a potential DSO buyer doesn't know what he or she needs.

A logical point to start reducing some of this confusion is with the bandwidth and sample-rate issues. Bandwidth normally refers to the bandwidth of the electronics in the DSO's input path up to and including the digitizer, but there are other important bandwidths to consider. First you need to understand the sampling system.

It's important to distinguish between repetitive events, such as those you might observe with a nonstorage analog scope, and single-shot events, such as those that require a storage scope. DSOs made for repetitive events can use equivalent-time sampling methods such as random-repetitive sampling or sequential sampling. (If you aren't familiar with these terms, see **box,** "DSO sampling methods.") A DSO can capture repetitive events, even those with repetition rates as low as 1 Hz, with random-repetitive sampling if you don't mind waiting a few tens of seconds to complete the acquisition. If you often work with signals that repeat much more slowly than 1 Hz or with truly one-time events, you need a DSO with real-time sampling.

A scope's nominal bandwidth is the proper bandwidth to consider when using equivalent-time sampling. When you're using a DSO in real-time sampling mode to look at

The 50,000-word record length on all channels of LeCroy's 7200 DSO makes it a top performer on long events needing high timing resolutions. This 400-MHz DSO is capable of sampling four channels simultaneously at 1G samples/sec.

single-shot events, one and sometimes two other bandwidths are also important. These two bandwidths are that of the signal you intend to examine with the DSO and that of the DSO's input path.

Often the bandwidth of a DSO's input path remains the same whether you use the scope for single-shot or repetitive applications, but not always. For example, Hewlett-Packard's HP54502A DSO has a 400-MHz bandwidth for repetitive signals, but its input bandwidth for real-time applications is 100 MHz. HP limits the 54502A's bandwidth to 100 MHz because the company believes this bandwidth represents the fastest signal you can examine at the DSO's highest real-time sample rate, 400M samples/sec.

The question of how much usable signal bandwidth a scope can achieve at a given sample rate is a subject of interest and heated discussion with both DSO manufacturers and users. The question is difficult to answer because the answer depends on how much information you want. And some DSO manufacturers argue that the bandwidth at a particular sample rate also depends on the processing the DSO performs on the waveform when it uses a digital reconstruction filter.

An often-mentioned term in this discussion is the Nyquist sample rate. The Nyquist criterion states that to reconstruct a signal, you must sample it at a minimum rate

incrementally greater than twice its bandwidth. For DSO applications, this rate can only be considered adequate on unchanging periodic waveforms. The most important point of the Nyquist sample rate is that it represents the minimum sampling speed guaranteed to prevent undersampling and aliasing. Sampling a waveform at the Nyquist rate does not, however, guarantee that you can faithfully reconstruct the signal. Faithful reconstruction usually demands sampling well above the Nyquist rate.

For a signal without any waveform processing, the general rule of thumb is to sample at 10 times the bandwidth of the signal. A simple linear interpolation between the points of a waveform recorded at this sample rate enables you to capture the basic character of the waveform, and measurements such as pulse width will have some measure of repeatability regardless of where the sample points fall on the waveform.

The real issue with any scope—whether analog or digital—is how well it reproduces the waveform. For measurements to be meaningful, you have to trust your instrument. Although it is difficult to verify the accuracy of a DSO on dynamic waveforms—whose scope could you use as a benchmark?—you can at least check for repeatability. If you measure the same waveforms numerous times and don't get repeatable results, you can be certain those measurements

DSO sampling methods

DSOs use three different methods to sample signals prior to digitizing. One is real-time sampling; the other two are considered equivalent-time sampling methods and are only useful on repetitive waveforms.

Real-time sampling is the most straightforward of the three and the only method suitable for examining single-shot events. In real-time sampling, the DSO samples the data signal continuously at the maximum sample rate or at a reduced rate for long-timebase settings. It then routes the data in one of two ways: into an A/D converter and then into memory configured as a shift register or into a charge-coupled device that operates as an analog shift register. When the DSO senses the trigger event, sampling stops in the case of pretrigger viewing, or it continues until the desired time for post-trigger viewing.

High-speed real-time sampling and conversion systems are expensive to build and are not yet available in DSOs for sampling beyond 2G samples/sec. For this reason, many people use equivalent-time sampling to provide the equivalent of much higher sample rates. You can only use equivalent-time sampling to examine a repetitive waveform.

In random-repetitive sampling, one form of equivalent-time sampling, the DSO acquires multiple sets of sample points to cover the period you select with trigger and timebase settings. The DSO takes each set of samples in a manner identical to that of real-time sampling. Because the DSO is sampling asynchronously with respect to the signal, each set of samples has a random relationship to the trigger. The DSO measures this time relationship and places each sample in the closest "time bucket." Eventually, the DSO will have taken enough samples to fill all the closely spaced time buckets. Using this method, a DSO can have very high timing resolution while retaining the ability to view pretrigger information.

Sequential sampling is the other equivalent-time sampling method. When operating in this mode, the DSO takes one sample each time it triggers. After each sample, the delay between the trigger event and the time when the DSO samples the waveform increases. After some period of time, the DSO acquires the complete waveform.

The advantage of sequential sampling is the ability to capture waveforms with very high bandwidths. Currently, DSOs with bandwidths as high as 40 GHz are available.

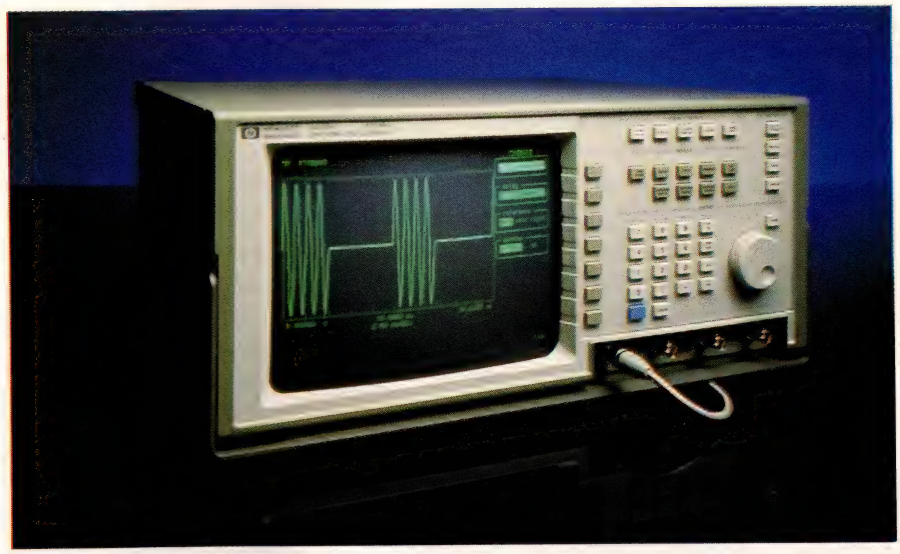
On the minus side, when a DSO uses sequential sampling it usually takes longer to acquire a waveform when compared with random sampling, and you cannot view pretrigger events except by using delay lines on the signal. A DSO would take about the same amount of time to acquire every point in a waveform when using either technique. Sequential sampling has a slight speed advantage; when using random sampling, a DSO acquires a small percentage of points more than once.

It's difficult to determine the usable single-shot bandwidth of a DSO because it depends on how much information you need.

aren't accurate.

HP's 54502A can reconstruct a waveform with reasonable repeatability and accuracy using the minimum number of sample points per period. The company claims that its DSOs with digital reconstruction filters have real-time bandwidths of one quarter their sample rates. For example, the 54502A's timing measurements, such as period and pulse width, are repeatable within about 10% of the sample period, or 250 psec at the maximum sample rate.

HP does not provide reconstruction filters on DSOs intended primarily for equivalent-time sampling. Consequently, the company considers the real-time bandwidth of these scopes to be one tenth of their sample rates, as is the case for the 54503A.



At $4950, the 500-MHz 54503A from Hewlett-Packard gives you the advantages of a digital scope at an analog-scope price.

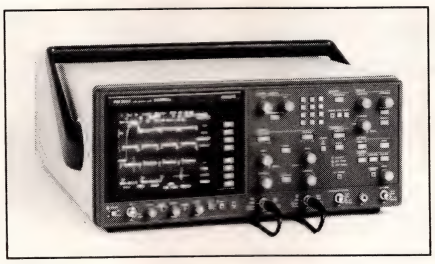
Choose fidelity or repeatability

Philips (Fluke sells Philips products in North America) maintains that a real-time bandwidth of not more than one tenth of the sample rate is required for single-shot acquisitions. The company considers reconstruction filters inappropriate because they alter the character of the observed waveform. Consequently, Philips does not offer reconstruction filters.

Furthermore, Philips claims that using a bandwidth-limited DSO on real-time events distorts the waveform unnecessarily. For example, using a 100-MHz bandwidth limit means that the amplitude of a 100-MHz signal will be attenuated by 3 dB, or 30%. The 3.5-nsec rise time associated with a 100-MHz bandwidth means fast edges are slowed considerably.

If you adhere strictly to Philips' recommendation of sampling at 10 times the bandwidth, the 500M-sample/sec rate of its PM3323 should let you observe waveforms containing frequencies as high as 50 MHz. Yet any pulse with a rise time of 7 nsec or less will have an information-content frequency higher than 50 MHz. In other words, by omitting the bandwidth-limiting filters, a scope manufacturer passes the responsibility for limiting the signal bandwidth to you.

The PM3323 maintains its full 300-MHz bandwidth in repetitive and single-shot acquisitions at 500M samples/sec. The data points acquired by the PM3323 follow higher frequency single-shot waveforms more closely, but timing measurement repeatability suffers because the DSO has less information about the value of signals between data points. Measurement repeatability suffers because any pulse with a fast rise time has a high frequency content. Without limiting the bandwidth before digitizing, you loose information by undersampling.



The PM3323 300-MHz DSO from Philips samples at 500M samples/sec.

Yet another approach to waveform reconstruction is that of Tektronix's 500M-sample/sec 300-MHz 2440 DSO. Tek claims single-shot bandwidths for sine waves of 2.5 samples per period, or 200 MHz. Although Tek has a reconstruction algorithm that is useful on sine waves, the repeatability of pulse measurements suffers at this sparse sample rate. Unless you limit the bandwidth, you'll get different results depending on the phase of the pulse in relation to the trigger. If you use the 2440's 100-MHz bandwidth limit (a feature you can invoke from the instrument's front panel), you'll get repeatability similar to that of HP's 54502A. (Tek's DSA 601 and 602 do not have reconstruction filters.)

If you're interested in using a DSO for fast real-time waveforms,

the best policy is to use a pulse generator to compare the performance of DSOs. Single pulses are the safest to use because there can be no doubt about whether the scope is operating in a single-shot mode or an equivalent-time sampling mode.

Take some measurements on multiple pulses and compare them for repeatability. Examine continuous pulse trains using equivalent-time sampling to see how they compare with the single-shot acquisitions. If you're looking for 2 or 3% timing accuracy and repeatability on a pulse-width measurement, you're going to have to settle for considerably lower real-time bandwidth at a given sample rate than will someone who's satisfied with 20% accuracy.

Aliasing is a potential problem

Most discussions of real-time bandwidth center around the maximum bandwidth at the maximum sample rate. But you should also consider operation at slower sweep rates, where the DSO may not be able to sample at the maximum sample rate due to the record length of the memory. In this case, the sample rate drops; normally, the scope's bandwidth remains unchanged. Now the DSO is undersampling, and you're wide open to aliasing problems. This hazard exists on every real-time oscilloscope, although some scopes post a warning when aliasing is or could be occurring.

One way some scope manufacturers have tried to protect you from this type of undersampling is through the use of glitch-capture circuits, which are peak detectors. With glitch capture, the DSO captures and displays any peaks that occur between sample points. The peak-detect feature can help keep you out of trouble and is a useful tool when looking for glitches over long time intervals. Glitch capture is a feature of the PM3323 and is also found on some DSOs from Tektronix.

If you think the sample-rate-versus-bandwidth controversy is entertaining, then you might also enjoy the resolution wars. Digitizers used on high-performance DSOs typically have resolutions of six to 12 bits, but a digitizer's resolution doesn't tell you much.

For resolution to be meaningful, you need to have clean electronics in the front end of the DSO. "Clean" means low nonlinearity in the amplifier section, low noise throughout the input path, and low noise and nonlinearity in the digitizer itself. Relating all of the normal digitizer specifications, such as monotonicity, linearity, and aperture uncertainty, to the performance of a DSO is not a simple exercise.

If you think of the resolution of a digital scope as analogous to the thickness of the trace on an analog scope, you can see the importance of high resolution, even though the vertical accuracy may be only ±2%. One attempt to quantify resolution is the effective-bits test recommended by the IEEE (see **box,** "Testing for effective bits").

The effective-bits test accounts for all noise and nonlinear distortion of the digitizer, but it does not account for linear errors in the signal path. These errors affect the sine wave's phase, amplitude, and dc offset. The effective-bits test also

Testing for effective bits

You can use the effective-bits test to compare the output of a real digitizer, the DSO in this case, with that of a theoretically perfect digitizer. To perform the test, input a pure sine wave—one whose harmonics are below the sensitivity of the digitizer—to the DSO. Analyze the digitized data with a computer to find the perfect sine wave that most closely matches the digitized sine wave. Then, use the computer to ideally quantize that sine wave to the same resolution as your digitizer.

Next, form two sets of values. In the first set, subtract the real digitizer's output, sample by sample, from the computer-generated perfect sine wave. In the second set, subtract the ideally quantized values—the results of an ideal digitizer—from the computer-generated sine wave. Reduce the two resulting sets of data to a real digitizer rms error value and an ideal digitizer rms error value. You can then compute effective bits using the following equation:

$$\text{effective bits} = \text{real digitizer bits} - \text{lost bits},$$

where

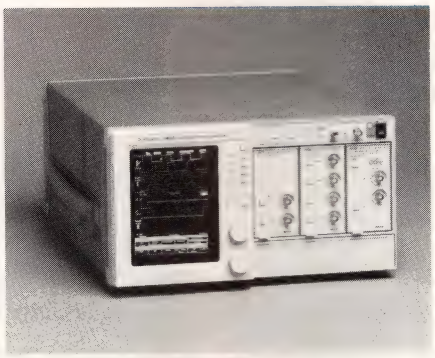
$$\text{lost bits} = \log_2(\text{real digitizer rms error} \div \text{ideal digitizer rms error}).$$

If a measurement isn't repeatable, you can be certain that it's not accurate.

doesn't take into account the attenuation of a signal with frequency. Furthermore, because a DSO may have localized nonlinearity in gain, the number of effective bits can vary depending on the amplitude of the waveform used in the test. For the complete story, you need a matrix of effective-bit values that cover the full frequency and amplitude range of the digitizer.

In the past, the only resolution comparison between DSOs has been the number of bits coming out of their digitizers. Such comparisons are highly unreliable because the bits coming out of a digitizer can be rendered meaningless by noise in the front-end analog circuits or in the digitizer itself. **Table 1** shows the number of effective bits for some DSOs used for single-shot acquisitions. Remember, this number doesn't tell the whole story, but it's the best measure now available.

In real-time applications, the only way to increase resolution is through oversampling, which a DSO can do when examining lower-bandwidth signals. HP has used this technique on the 54111D, and LeCroy has this capability in its 7200.



Intended for repetitive waveforms, the 11403 1-GHz DSO from Tektronix is a color-display upgrade of earlier models.

Averaging for more resolution

You can increase the effective bits of resolution on equivalent-time-sampled waveforms using averaging, but there are some restrictions. Averaging, a feature available on all high-performance DSOs, eliminates noise that is not correlated with the trigger, whether the noise is in the circuit under test or internal to the DSO. Because you can increase resolution with averaging on repetitive waveforms, resolution is less of an issue in DSOs dedicated to repetitive-waveform applications. Averaging can be a real asset in making precise waveform measurements, but it must be used judiciously.

Record length is another specification in which you can see quite a bit of variation. LeCroy's 7200 comes out on top with a record length of 50,000 points, the highest for any DSO with a bandwidth greater than 100 MHz. Furthermore, the 50,000-point memory is available on all channels. Tek's DSA 601 and 602 support 32,000 points with one channel active, 20,000 points per channel with two channels active, and 10,000 points per channel when you use four channels.

There are several reasons you might want these long record lengths. Having a long record

Table 1 — Recently introduced high-performance DSOs

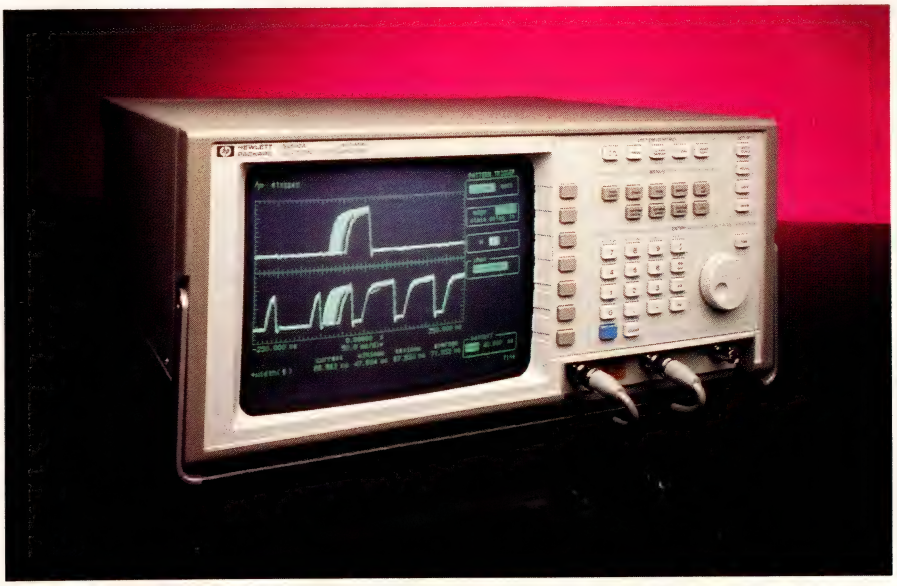
Manufacturer	Model	Maximum channels	Bandwidth (MHz)	Sample rate (M samples/sec)	Record length (points)	Effective bits[4] frequency(MHz)					Display update time (sec) @ 10 nsec division		Display		Price
						1	10	40	100	250	Acquire and display data	Average 32 acquisitions and display	Type[5]	Resolution (height x width in pixels)	
Hewlett-Packard	54502A	2	400[1]	400	2k	6.0	6.0	5.9	5.4	—	3000 points/sec	5.0	M	451Hx256V	$6450
	54503A	4	500	20	2k	—	—	—	—	—	3000 points/sec	5.0	M	451Hx256V	$4950
LeCroy	7200	4	400	1000[2]	50k	NA[6]	NA	NA	NA	NA	NA	NA	M	500Hx2000V	$32,900[9]
Philips	PM3323	2	300	500	4k	6.5	5.9	5.7	—	—	0.020[7]	NA	M	Analog	$7750
Tektronix	11403	12	1000	20[3]	10k	—	—	—	—	—	0.020[8]	1.5	C	552Hx704V	$21,100[9]
	DSA 601	12	1000	1000[3]	32k[3]	7.2	7.2	NA	6.8	6.5	0.020[8]	1.5	C	552Hx704V	$25,175[9]
	DSA 602	12	1000	2000[3]	32k[3]	7.2	7.2	NA	6.8	6.5	0.020[8]	1.5	C	552Hx704V	$31,275[9]

Notes: 1. Realtime bandwidth is 100 MHz
2. As many as four channels at this sample rate
3. Maximum on one channel
4. Typical values, not a specification
5. M=monochrome; C=color
6. NA=information not available
7. Display update only. Complete record requires 0.5 sec
8. Complete 500-point record
9. Price includes plug-ins for two channels, probes extra

length on real-time acquisitions means that you'll get better timing resolution at sweep speeds at which another scope might have to reduce sample rates to fit the data into memory. For example, LeCroy's 7200 can store a complete 50-μsec waveform sampled every nanosecond. By comparison, HP's 54111D, although capable of sampling every nanosecond, can acquire samples no more often than approximately every six nanoseconds to capture a 50-μsec event.

With real-time events, when you don't get a second chance, a high-resolution record of an event is important. Yet even in equivalent-time sampling situations, a long record length can be helpful. Calculated measurements such as FFTs provide better resolution when the input record length is long.

When comparing DSOs, you need to consider what record length is usable for which operation. For example, the PM3323 DSO has a 4000-point record length that is usable on repetitive events, but for real-time events, you are limited to a 512-point record length. The HP 54502A has a 2001-point record length but only displays 500 points.



With a sample rate of 400M samples/sec, the 54502A DSO from Hewlett-Packard offers bandwidths of 400 MHz for repetitive waveforms and 100 MHz for single-shot waveforms.

Display processing speeds vary

In many ways DSOs are becoming virtual instruments. The DSO takes voltage-versus-time measurements and, using this data, it can perform a wide range of functions depending on the processing capabilities built into the scope. All high-performance scopes also have means of transferring data to computers for further analysis through either IEEE-488 or RS-232C interfaces, although this capability is optional on some DSOs. A few scopes, such as LeCroy's 7200, contain IBM PC-compatible floppy-disk drives, which enable you to move acquired data to a PC without connecting any cables.

There are two major considerations when discussing display processing and measurements performed by DSOs. The first is what processing functions the DSO can perform; the second is how fast the scope can process the data. Performing a computation within a scope is faster and probably more accurate than performing the function manually. Compared with analog scopes that lack computational capabilities, even the cursor-controlled readouts of the simplest DSOs represent a major improvement.

As electronics technology progresses and more signal processing power is packed into DSOs, some scopes, most notably Tek's DSA 601 and 602, can perform signal-processing functions at an impressive rate. The DSA 601 and 602 can perform averaging on 32 waveforms and display the results in 1.5 sec. Ordinary acquisitions plus screen updates take 20 msec. These update speeds make these scopes feel like analog scopes, a quality not all digital scopes can exhibit.

When you use a DSO for making a series of automated measurements, these high processing speeds can make a noticeable difference. Even in manual or semiautomatic use, when you're performing many measurements—especially ones that take a dozen or more seconds—you'll begin to appreciate the extra speed that's possible when using a scope with a high processing rate.

Preprogramming speeds work

The number of preprogrammed measurements you can select on DSOs starts at 16 standard pulse parameters and goes to about 40. If these measurements don't fit your needs, you can often customize them. For example, if you want a nonstandard rise-time measurement, say 5% to 95%, most DSOs let you program the limits through their front panels.

One attempt to quantify resolution is the effective-bits test, which is recommended by the IEEE.

Obviously, with a computer and an IEEE-488 interface, you could make virtually any measurement. However, the measurement would take more time because the DSO would have to transmit an entire screen of raw data. Any time you can perform a measurement within the scope instead of transmitting the raw data, you'll get a much faster response.

Before dismissing some function as an unnecessary frill, you need to look closely at what the feature can do for you. For example, you may consider the ability to differentiate a waveform another unnecessary feature, but if you often look at a waveform's slew rate, differentiation will give you the picture quickly and graphically.

Tek's 600 family of scopes offers a dejitter feature that is new to oscilloscopes. Using their high-speed signal-processing capability, these scopes can capture a waveform even if you can't get a stable trigger on it. The DSOs perform correlation computations to time-align each waveform acquisition to get the best fit. You must use this capability judiciously, because you'll find it difficult to differentiate trigger jitter from jitter in the waveform. But dejittering does give you a better image when you have waveforms that are not well synchronized with the trigger.

Some DSOs can perform FFTs and inverse FFTs. The PM3323 can handle 2000 points, Tek's DSA 601 and 602 can process as many as 32,000 points, and LeCroy's 7200 can process 50,000 points. These functions can be valuable when you need them to look at noise or harmonic distortion or to analyze modulation or feedback. These capabilities can't usually match the performance of a dedicated spectrum analyzer, but they can be a help, especially when making measurements on single-shot waveforms.

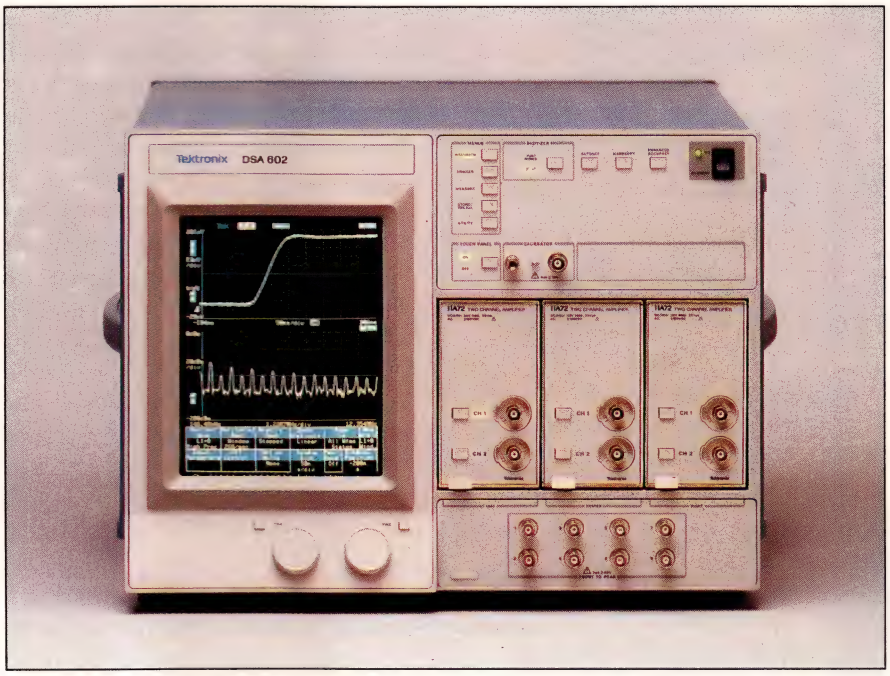
All high-performance DSOs can store both waveforms and setups in memory, but LeCroy has gone all the way on the 7200 with both a hard-disk and a floppy-disk drive for storage. The DSA 600 series from Tek offers as a $1000 option a 450,000-point nonvolatile memory. Although this option doesn't quite give you the capacity and flexibility of LeCroy's hard disk and floppy disk combination, it gives most users ample storage, and the recall times from nonvolatile RAM are faster than those of a disk.

Making DSOs easy to use

The relative ease of use of various DSOs is difficult to assess. All high-performance DSOs have menus for selecting functions, and the functions the DSOs perform dictate the number of menus. DSOs like LeCroy's 7200 or Tek's 600 series have many menus to control their numerous processing functions. You'll need some time to become familiar with all of the functions.

However, learning to operate any of these high-performance DSOs should not be difficult for a new user who has had some previous experience with either analog or digital scopes. The real issue is how much time you waste pushing buttons and twisting knobs once you become familiar with the scope.

Knobs can be an issue. All HP DSOs offer only one "soft," or programmable, knob. You use menus to select which parameter you want to set. Then you either key in the number with the numeric keypad or rotate the soft knob. Tek's high-performance lab scopes do HP one better by providing two soft knobs. The functions controlled by the soft knobs on Tek's scopes are clearly



A 1-GHz bandwidth and a maximum sample rate of 2G samples/sec make the DSA 602 from Tektronix a versatile DSO for both single-shot and repetitive waveforms.

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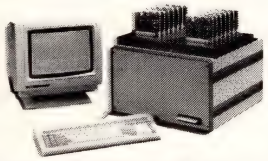

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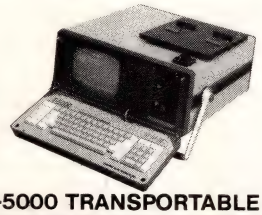

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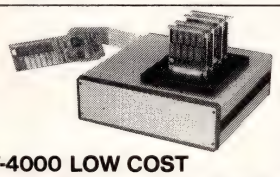

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marked on the display adjacent to the knob, so there's no confusion about which knob is handling which function—a potential problem when you have more than one soft knob.

Some DSOs, such as those from Philips and LeCroy and portable DSOs from Tek, have dedicated knobs or rocker switches that increment or decrement values. LeCroy uses dedicated knobs on commonly used functions. There can be no doubt that these dedicated knobs save both the new and experienced user time adjusting the scope. The time advantage, however, may not be as large as you would expect because all DSOs—whether they have soft or dedicated knobs—can store commonly used setups for instant recall. Furthermore, all high-performance DSOs have an autosetup key that will get a stable trigger and a reasonable sweep speed and vertical gain on almost any signal. Often you only have to make a timebase and perhaps trigger-delay adjustment to zero in on exactly what interests you.

Two soft knobs handle these adjustments nicely, but you can make a case that dedicated knobs make scope operation faster. The trouble is that with a high-performance DSO such as Tek's 602, you can be using 12 channels. It's impractical to provide dedicated knobs for that many channels.

Because there is so much variety in DSOs, you really need to study the data sheets to find the scope that is best for your application. In fact, you may need to test drive several scopes before you make your final decision. Unlike analog scopes, you can't take DSO features for granted. EDN

Reference

1. Conner, Doug, "High-performance DSOs present users with plenty of choices," *EDN*, December 22, 1988, pg 94.

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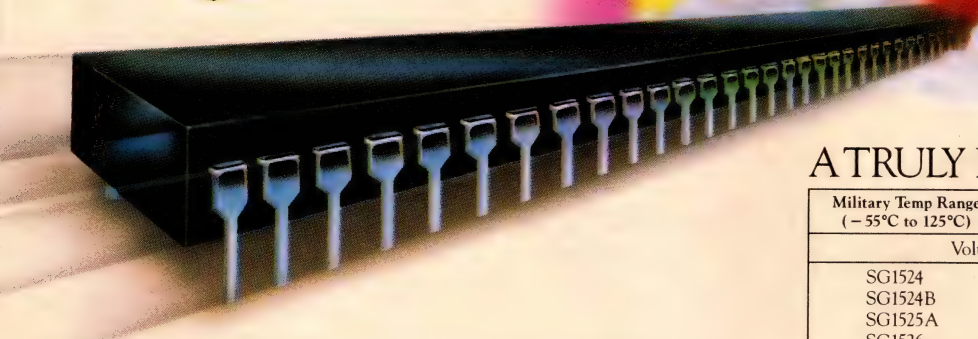

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SG1529	SG3529
Current Mode	
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SG1842	SG3842
SG1843	SG3843
SG1844	SG3844
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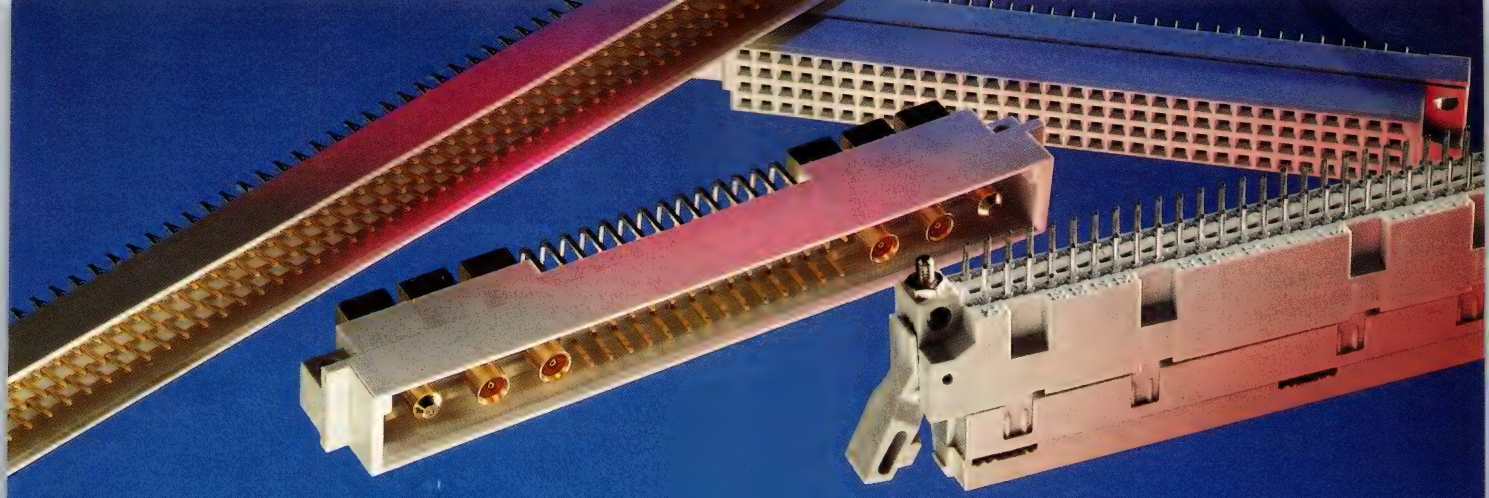

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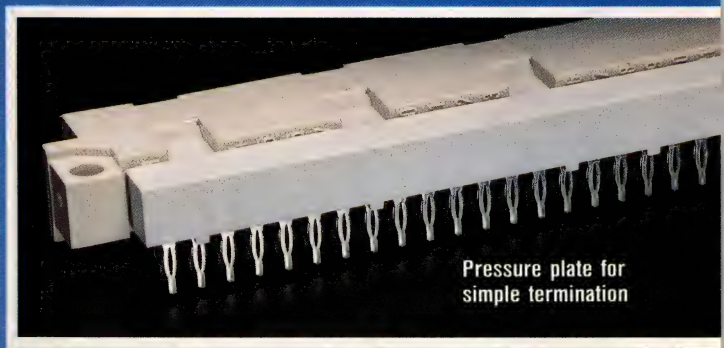

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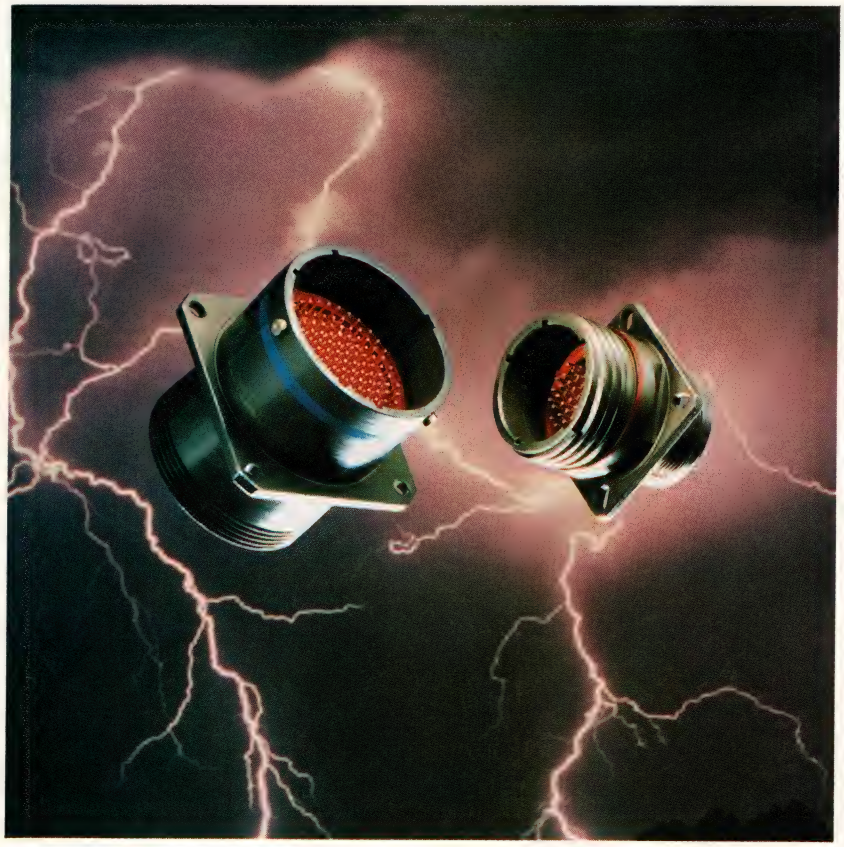

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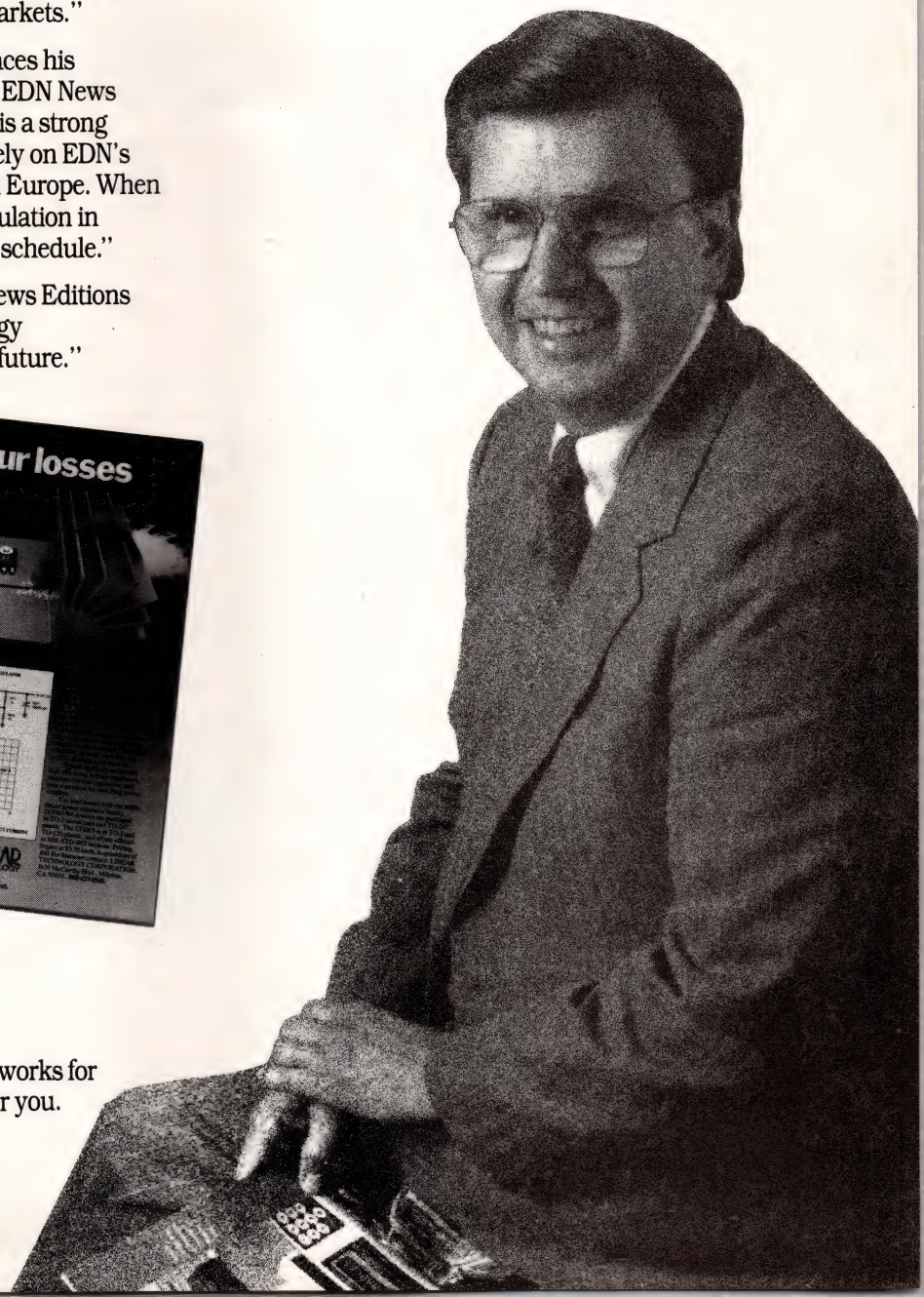

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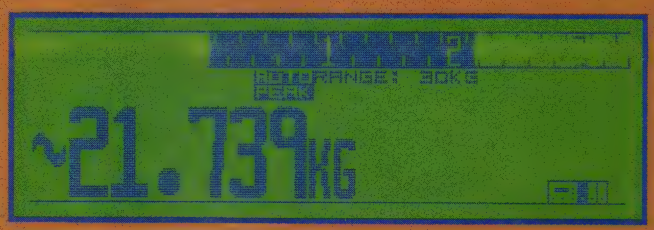

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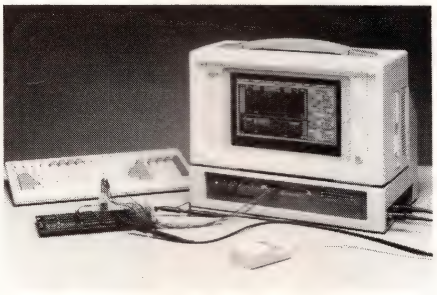
6120 Hanging Moss Rd. Orlando, FL 32807 Phone: 407-678-6900 Fax: 407-677-5765

PC-based DSO/logic analyzer includes the computer within its portable case

The Omnilab II is the latest version of the vendor's Omnilab 9420, a multifunction, PC-based instrument whose operator interface uses a proprietary windowing system. Included are a 100-MHz bandwidth, a 204M-sample/sec DSO with at least two channels, a logic analyzer with as many as 96 channels that produces displays time aligned with the DSO's, an arbitrary waveform generator, a 24-channel digital pattern generator, and a 500-MHz frequency counter. Unlike its predecessor, which uses a separate PC that you must supply, this version is a single portable unit that includes a PC with a 20M-byte hard



disk and a 1.2M-byte floppy-disk drive.

A software package called OmniMacros facilitates creation of test routines without conventional programming. With OmniMacros, you press keys and move a mouse until a test works the way you want it to. You then record the test setup on disk. When recalled, a setup reproduces not only the control settings, stimulus patterns, and triggers—it can also display reference data (for example, waveforms obtained from a known-good unit) for comparison. Setups can also include prompts to a technician indicating, for example, where next to place a DIP clip. With an optional IEEE-488 interface, the unit can control external instruments. From $14,000.

Orion Instruments Inc, 702 Marshall St, Redwood City, CA 94063. Phone (800) 729-7700; in CA, (415) 361-8883. **Circle No. 681**

Portable logic analyzers incorporate dual-channel digitizing scope

Two portable logic analyzers, the HP 1652B and HP 1653B, incorporate a dual-channel digitizing oscilloscope section that lets you make precision, time-correlated analog and digital signal measurements in addition to performing conventional logic and state analysis. The oscilloscope sections of both instruments feature two channels that digitize signals at rates to 400M samples/sec. The $11,800 HP 1652B and $7900 1653B furnish 80 and 32 logic-analysis channels, respectively.

In state-analysis mode, the 1652B operates at 35 MHz max; the 1653B operates at 25 MHz max. Both instruments make timing-analysis

measurements at a fixed rate of 100 MHz, recording only when a logic level changes on one or more channels. With the instruments' glitch-capture feature enabled, the maximum capture rate is 50 MHz. For both logic-analysis modes, the analyzer section stores 1024 samples per channel.

Each of the scope channels can take 400M samples/sec and provides 100-MHz single-shot and repetitive bandwidths. The instruments store waveforms in independent, 2k-point buffers. Their oscilloscope sections can automatically perform several measurements on captured waveforms, including determining pulse width, frequency, period, rise time, fall time, p-p voltage, and overshoot.

Hewlett-Packard Co, Box 10301, Palo Alto, CA 94303. Phone (800) 752-0900. **Circle No. 682**

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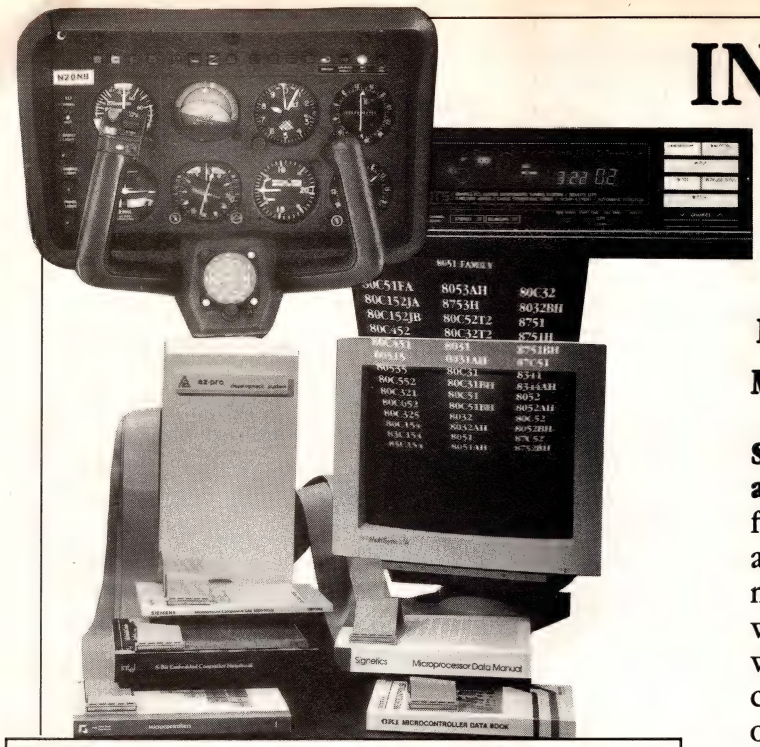

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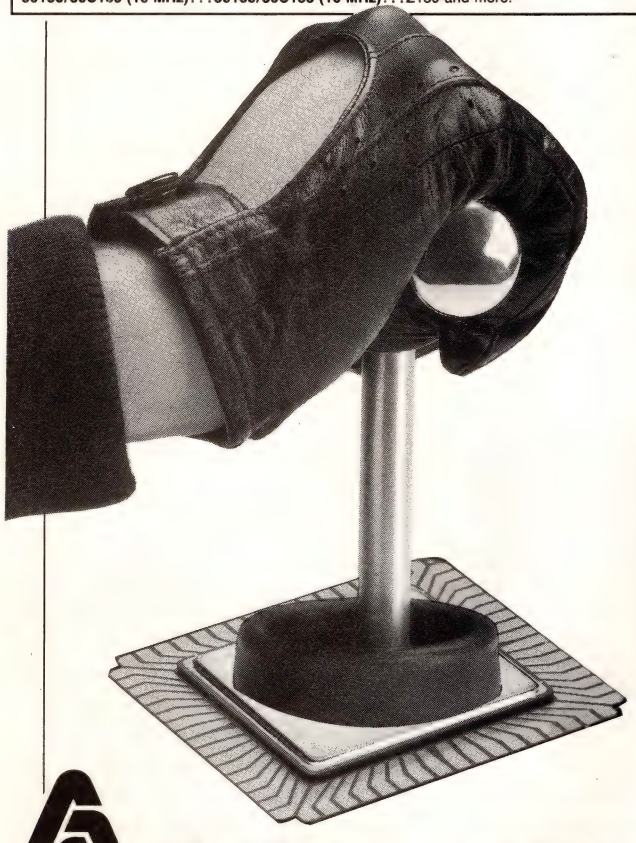

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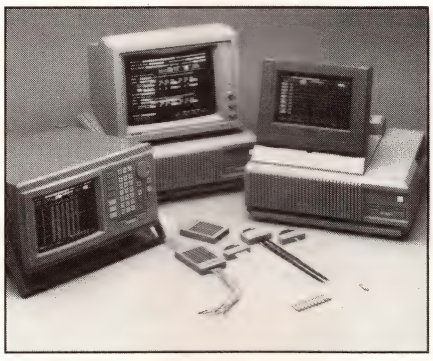
Logic analyzer triggers on hardware faults to 2 GHz

Customarily, logic analyzers do not trigger directly on faults; triggering must conform to restrictions imposed by the instrument. The 3001HSM hardware-analysis logic analyzer, however, lets you set up trigger conditions based on how you think about hardware problems. For example, it will trigger directly on setup times that violate limits you specify or on pulse durations narrower than a value you supply.



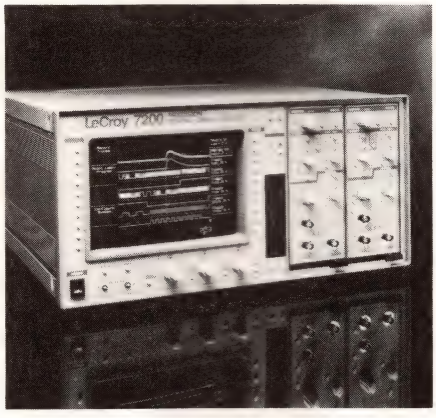
"Leadsets" (units that others would call pods) modify the instrument's capabilities. One leadset lets the analyzer acquire data asynchronously at 2 GHz on four channels and store 12,000 words. A leadset having a maximum asynchronous acquisition rate of 400 MHz on 20 channels uses transitional timing to effectively increase memory depth. For state analysis, the instrument can acquire data on 18 channels at 300 MHz (200 MHz in dual-threshold mode, which is useful for spotting marginal-amplitude conditions). You can also add leadsets that digitize two analog waveforms to 11 levels at 400M samples/sec.

The instrument uses a large pc card, the 30HSM. As many as ten 30HSM boards can plug into the company's Prism 3002 modular logic-analysis systems to give the systems a capacity of 200 fully time-aligned channels. The 30HSM costs $6500; the 3001HSM carries a base price of $11,000. Leadsets range from $900 to $2400. Delivery is eight weeks ARO.

Tektronix Inc, Box 12132, Portland, OR 97212. Phone (800) 426-2200. **Circle No. 683**

DSO takes 1G samples/sec on four channels and performs high-speed DSP

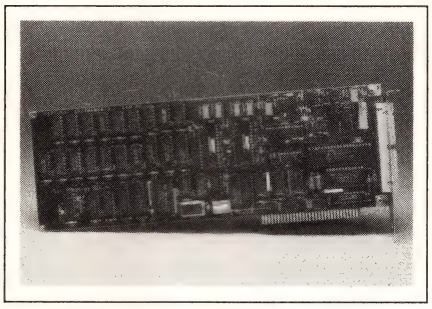
By using an ADC on each channel, the 7200 high-performance digitizing scope can simultaneously capture transient data at 1G samples/sec on four channels with 8-bit resolution and 400-MHz bandwidth. The unit also contains a high-speed digital signal processor, which, combined with a 50k-point-per-channel waveform memory and an algorithm that doesn't force a power-of-two sample-set size, allows rapid computation of signal spectra with a resolution 50 times greater than that of spectra produced by FFT analyzers that use a waveform memory 1,000 samples deep.



Other DSP capabilities include windowing with a choice of four window types, FIR filtering, and signal averaging. With a sacrifice in bandwidth, these capabilities can extend the scope's dynamic range to 11 bits. With repetitive signals, which the unit effectively captures at 20G samples/sec, you can obtain the 9.5 bits of effective resolution at the full, 400-MHz bandwidth.

A 20M-byte hard disk stores waveforms and test setups. A 720k-byte floppy-disk drive facilitates transporting data to an IBM PC for off-line analysis. The unit also includes RS-232C, IEEE-488, and Centronics ports. From $32,900.

Le Croy Corp, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977. Phone (800) 553-2769; in NY, (914) 425-2000. TWX 710-577-2832. **Circle No. 684**



PC-Based Analog/Digital I/O Package

The Lab-PC is an analog/digital data-acquisition card for the IBM PC bus. The card is available with several software packages including drivers for Microsoft C and QuickBasic. The card can acquire analog data from eight single-ended inputs with 12-bit resolution at 62.5k samples/sec. Gain is software programmable in seven steps from one to 100. The board also contains a pair of 12-bit D/A converters with double-buffered inputs.

There are 24 TTL I/O lines, organized as three 8-bit ports. Each line can sink 24 mA to ground. Two of the lines can supply 1 mA at 1.5V. Also included are three general-purpose counter/timers. The board makes data transfers to memory under DMA control, but if all the computer's DMA channels are occupied, it can also use interrupt-driven or programmed transfers. $695; drivers for QuickBasic and C, $95; LabWindows data-acquisition and analysis software, $495.

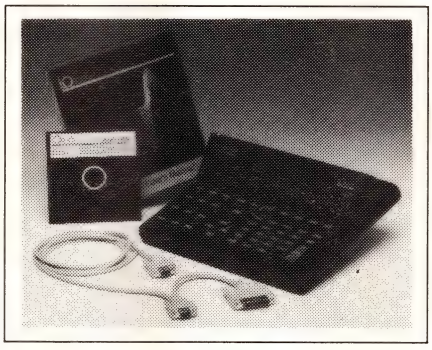
National Instruments, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 433-3488. FAX 512-250-9319. **Circle No. 425**

Frequency/Time Analyzer With 8000-point memory

The HP 5372A frequency and time-interval analyzer improves on its predecessor, the revolutionary 5371A, in several ways. Both instruments continuously measure frequency and time intervals without dead time, and graphically display how these parameters vary as a function of time. The 5372A stores eight times as many measurements as does the earlier instrument; it computes histograms faster, and it operates to 2 GHz (compared with 500 MHz for the 5371A) without an external prescaler. Like many digital scopes, the 5372A can use pretriggering to let you examine effects that lead to a transient condition. An optional, high-speed Fastport interface transfers 40,000 measurements/sec to an external controller. $28,000; 5371A, $23,000.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 426



IEEE-488 Bus Analyzer

The Analyzer488 troubleshooting tool transcends the usual lights-and-switches boxes that are today's common IEEE-488 troubleshooting tools. This stand-alone benchtop unit, which, by use of the accompanying software you can also control through a PC's RS-232C port, provides a small keypad and a 20-character alphanumeric display. Displaying bus operations in several formats, the unit includes a message mode that translates bus commands into mnemonic bus messages. The unit also allows you to monitor control signals.

You can select from three modes of operation: a bus-analyzer/monitor mode; a bus-controller mode; or an instrument-simulator mode. When operated as a bus monitor or analyzer, the unit resides on the IEEE-488 bus in a nonintrusive mode. It samples as many as 32,000 transactions at a rate as high as 1M byte/sec. Triggering sequences let you capture pretrigger and post-trigger transactions. You can also use a search-and-mark feature to scan through the collected information. The instrument provides a printed record of bus transactions through its RS-232C port or through an attached IEEE-488-compatible printer. Analyzer, with software and interface cable, $1495.

IOtech Inc, 25971 Cannon Rd, Cleveland, OH 44146. Phone (216) 439-4091. FAX 216-439-4093. TWX 650-282-0864. **Circle No. 427**

IEEE-488 Interface That Works From Sun SCSI Port

The SCSI488/S controller lets you control IEEE-488-based instruments from the SCSI port of Sun Microsystems workstations. Furthermore, when several workstations are interconnected via a local-area network, you can control the instruments equally well from any node on the network. Driver software that supports true multitasking, exception handling, and error correction accompanies the interface. You can use these drivers with programs written in any high-level language that supports Unix-system services. $1495; Sun Unix version of DaDISP, waveform-analysis and display package, $2495.

IOtech Inc, 25971 Cannon Rd, Cleveland, OH 44146. Phone (216) 439-4091. FAX 216-439-4093. TWX 650-282-0864. **Circle No. 428**

Logic Analyzers

The logic analyzers in the PL1000 line incorporate three slots that let you configure them to monitor simultaneously as many as 144 channels at 500 MHz (72 channels at 1 GHz) or 192 channels, synchronous or asynchronous, at 100 MHz (96 channels at 200 MHz). You can in-

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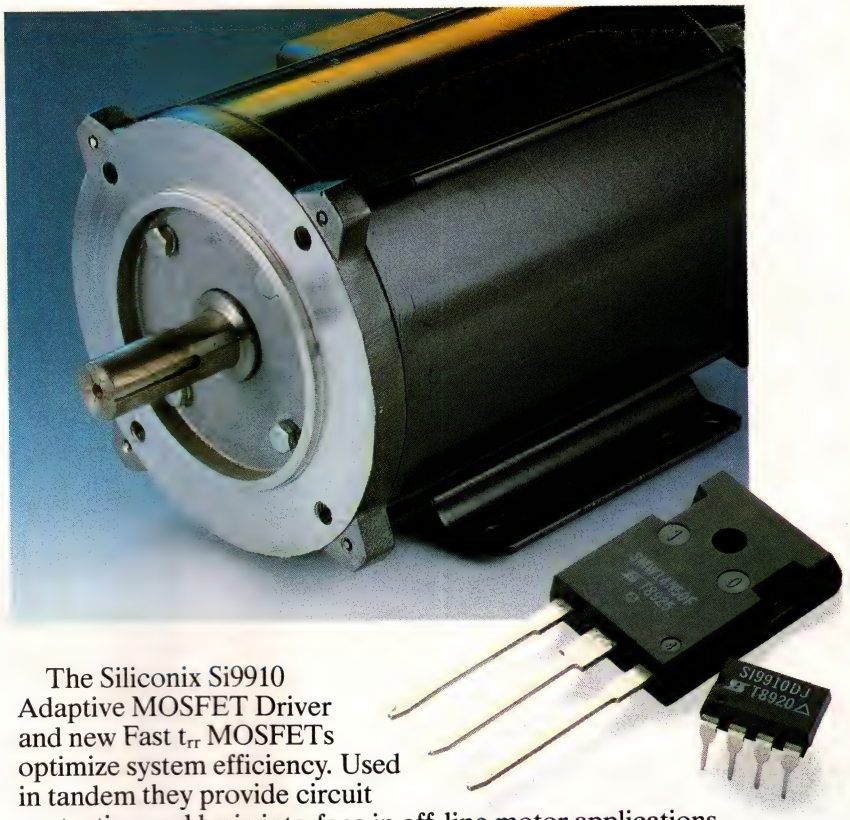

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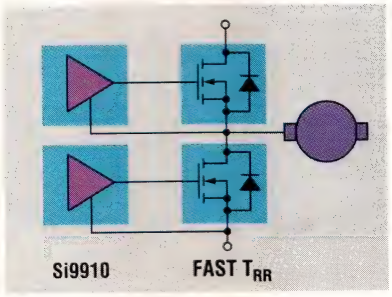

The Si9910 and Fast t_{rr} MOSFET family: system solutions for more efficient off-line control in motor drive and power supply applications such as major appliances, fans and blowers, industrial controllers, automobiles, power hand tools and UPS.

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termix modules to create, for example, a unit with 48 500-MHz channels and 64 100-MHz channels with cross-triggering and time alignment. Or you can include a 64-channel, 50-MHz pattern generator with 1k or 4k bits of pattern memory per channel. The PL1000 connects to your IBM PC/AT-compatible computer via a proprietary high-speed parallel interface; the PL1000+, which incorporates such a computer and interface, acts as a portable high-performance logic analyzer. The menu-driven controlling software runs under MS Windows. The vendor offers an extensive set of 8-, 16-, and 32-bit disassemblers. From $6195.

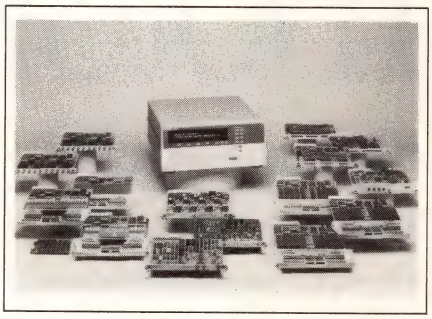
Kontron Electronics Inc, 630 Clyde Ave, Mountain View, CA 94039. Phone (800) 227-8834; in CA, (415) 965-7020. FAX 415-965-3505. TWX 910-965-7020.

Circle No. 429

Low-Power Data-Acquisition Card

The SBS-2300, an intelligent data-acquisition board based on the HD64180 μP, contains a 12-bit ADC, an analog multiplexer that you can connect for four differential or eight single-ended inputs, two analog outputs derived from 12-bit DACs, and 48 digital I/O lines. In addition, the board contains a keypad port, three programmable serial ports, a programmer for EPROMs and EEPROMs, and 32k bytes of RAM. Even with all these capabilities the board consumes only 600 mW. Included with the board is the CAMBasic II programming language, which supports 32 background tasks, including measurement of frequency and generation of pulse trains. An optional module permits networking of 32 SBS-2300s and an IBM PC-compatible computer. $595.

Octagon Systems, 6510 W 91st Ave, Westminster, CO 80030. Phone (303) 426-8540. FAX 303-426-8126. **Circle No. 430**



Low-Cost VXIbus Instruments

A group of about 24 instrument modules for the VXIbus includes 15 B-size units whose prices range from $400 for a breadboard module to $2100 for an 18-GHz microwave counter. A B-size 5½-digit multimeter costs $1200. B-size mainframes

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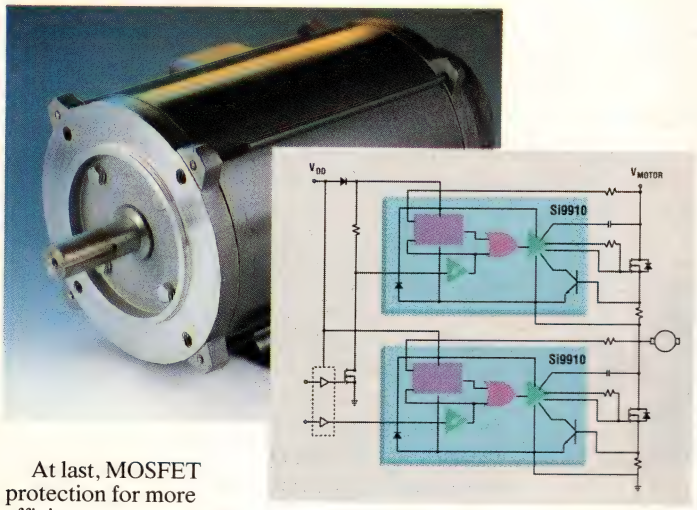

At last, MOSFET protection for more efficient motor control!
The Si9910 Adaptive MOSFET Driver provides dv/dt and di/dt control, shoot-through current limiting, undervoltage protection and short-circuit protection. In addition, it drives the high or low side of an n-channel half-bridge.

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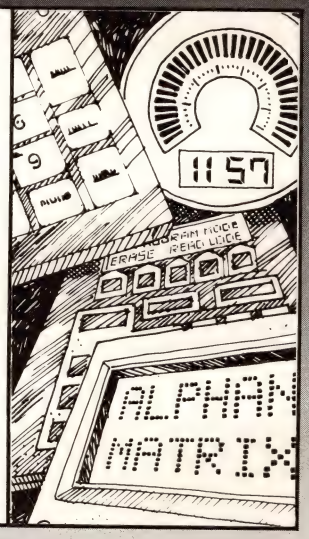

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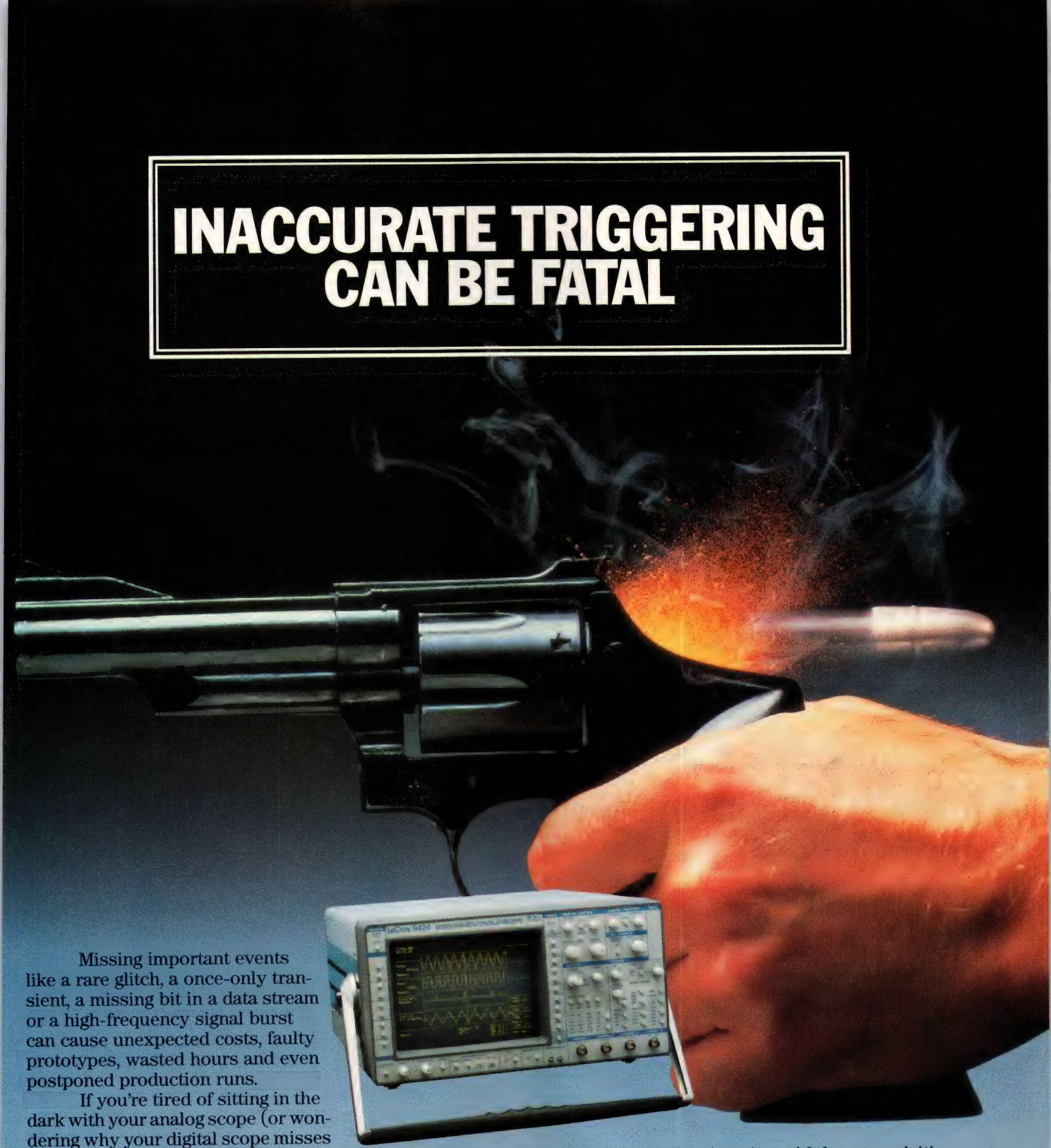

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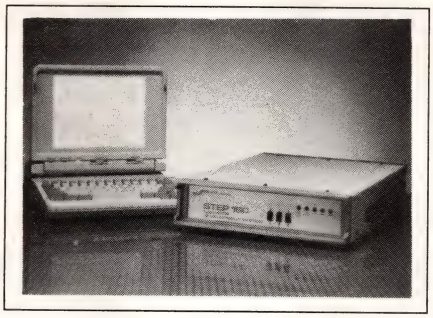
cost $2300 with a blank front panel and $2800 with controls and a display. Among C-size offerings are a 6½-digit multimeter for $3500 and a 5½-digit multimeter for $1600. An upgraded version of the vendor's previously introduced full-width C-size mainframe costs $6275.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 431

Development System

The Step-160 nonstop development system is a hardware and software tool for development and debugging of software for real-time control systems based on embedded μPs. The IBM PC/AT-hosted unit allows monitoring and modification of control programs without halting their execution. The unit includes a high-level-language compiler, a source-code debugger, a cross-assembler, and a user-debug monitor. It permits access to all μP buses and includes analog and discrete digital input channels as well as TTL inputs. You can use the unit to capture data to disk. Data filtering and complex triggering enable the capture of significant information. Furnished software eases data analysis. $18,500. Delivery, 90 days ARO.

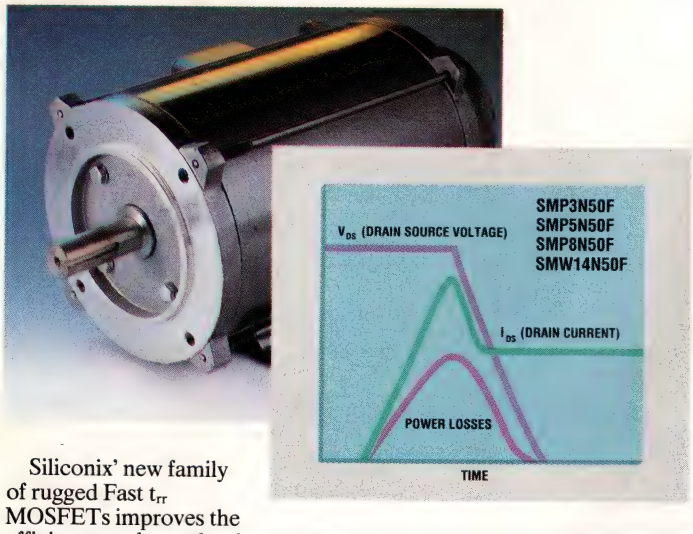


Step Engineering, Box 3166, Sunnyvale, CA 94088. Phone (800) 538-1750; in CA, (408) 733-7837. FAX 408-733-1073. **Circle No. 432**

Instrument-Command Syntax

A universal instrument-command syntax called TMSL (test and measurement systems language) is available for license to instrument developers. The vendor permits a licensee to extend the syntax (for example, to cover types of instruments not originally envisioned) without first obtaining approval to do so. With a license comes documentation that explains how to properly implement the syntax. The syntax, which will be used by all the vendor's VXIbus-based modules and all its IEEE-488-based instruments developed from now on, allows you to use the same commands to control different types of instruments that measure the same quantities. For example, if you now measure frequency with a counter that supports the syntax and later substitute a spectrum analyzer that also

More efficient Power MOSFETs improve your motor skills.



Siliconix' new family of rugged Fast t_{rr} MOSFETs improves the efficiency, reduces the size and lowers the cost of motor control systems. And their low $R_{DS(ON)}$, solid dv/dt rating and fully characterized diodes make it easier to achieve high system reliability.

Improve your motor skills! Ask for your Fast t_{rr} Motor Control Design Kit. Call our toll-free hot line now! **1-800-554-5565, Ext. 946.**

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2201 Laurelwood Road, Santa Clara, CA 95054

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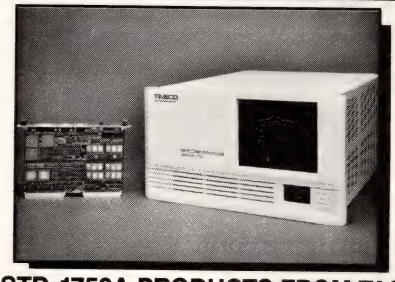
CIRCLE NO 11

MIL-STD-1750A SOLUTIONS



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WE ARE MIL-STD-1750A EXPERTS:

- CPU SPEEDS UP TO 40 MHZ
- OFF-THE-SHELF AND CUSTOM DESIGNS
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(714) 635-0550 **FAX (714) 535-3458**

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does, your software will require no modification to control the new instrument. License fee, $100.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 433

Scan-Test Module for ASIC Verifier

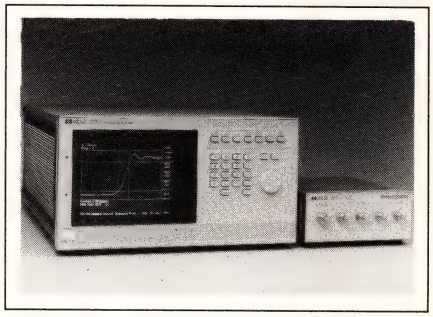
The Scan-Test Module is a plug-in board for the Logic Master XL ASIC verifier that allows you to use both parallel-vector testing and serial scan-mode evaluation. The board uses the XL's pin electronics and includes four high-performance drivers per board.

The board can store 1 million sequences of 4-bit data per driver, configured to represent whether to drive the ASIC pin high or low, whether to sense a high or a low from the ASIC pin, whether the pin is 3-stated or masked, and whether the data should be acquired. You can stack the memory to achieve memory depths of 2 million sequences with 2 channels or 4 million sequences with 1 channel.

The module supports a superset of the Joint Test Action Group's (JTAG) proposed scan-test specification, which is being considered by the IEEE as P1149. Other scan implementations supported include scan path, scan set, random-access scan, boundary scan, and level-sensitive scan. Where you need more than the four serial channels, you can add more scan-test modules to the Logic Master XL; it accepts as many as seven, giving you as many as 28 channels of 1-million-sequence-deep memory. Board, $33,000; Logic Master XL, from $55,000.

Integrated Measurement Systems Inc, 9525 SW Gemini Dr, Beaverton, OR 97005. Phone (503) 626-7117. FAX 503-644-6969.

Circle No. 434



34-GHz-Bandwidth DSO

The 4-channel HP 54123T digital sampling oscilloscope offers a previously unprecedented bandwidth of 34 GHz. The unit consists of a mainframe, the 54120B, and a sampling unit, which contains, in addition to the input circuits for conventional measurements, the pulse generator required for time-domain reflec-

...built in from the ground up. PITTMAN® brush commutated DC servo motors and gearmotors are made with premium quality materials and the very latest manufacturing and assembly techniques. *Every* motor is computer tested for all critical functions, under load and no-load conditions, and the print-outs of test data are kept on file.

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CIRCLE NO 14

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tometry used to locate discontinuities in transmission media. The instrument's firmware includes routines that construct histograms of noise and jitter, and assist in making eye-pattern measurements. $34,800.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.
Circle No. 435

VXI Module With 80 Digital I/O Ports

The 73A-412 is a C-size VXIbus module that contains 80 bidirectional digital I/O lines configured as 10 8-bit ports. Each line is TTL and CMOS compatible and can sink 24 mA. You can configure each port as a group of inputs or outputs. The ports communicate with external devices by using a 2-wire handshake and an enable pin. When a port is not enabled, its lines assume a high-impedance state. $1995.

Colorado Data Systems Inc, 3301 W Hampden Ave, Unit C, Englewood, CO 80110. Phone (800) 237-2831; in CO, (303) 762-1640. FAX 303-781-0253. **Circle No. 436**

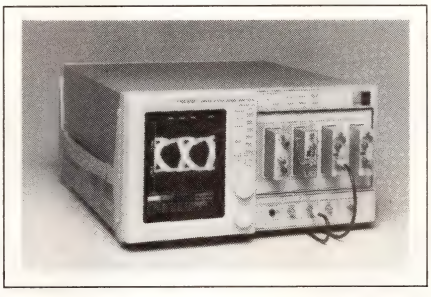
PC-Based ICE for Z8

The WICEZ8 in-circuit emulator for the Zilog Z8 μC supports real-time emulation at clock rates to 16 MHz. You use the emulator with an IBM PC or compatible computer; the vendor supplies software that enables the PC to control the ICE hardware via an RS-232C interface running at 38.4k bps. The windowed user interface lets you continuously monitor 30 memory locations, 17 stack locations, eight breakpoints, and a real-time clock. The 32k-byte emulation memory maps into target-system emory in 2k-, 4k-, 8k-, or 16k-byte blocks. The unit's symbolic debugger can use files generated by debuggers from 2500 AD, Microtek, and Zax. $995.

Wytec Co, 185C E Lake St, Suite 140, Bloomingdale, IL 60108. Phone (312) 894-1440. FAX 312-307-9809. **Circle No. 437**

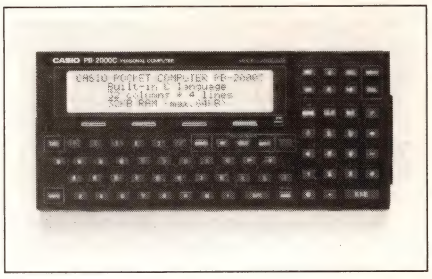
Communications-oriented 40-GHz-Bandwidth DSO

The CSA 803 communications signal analyzer is a sequential equivalent-time-sampling DSO with several capabilities focused on the needs of engineers who develop high-speed communications systems, including fiber-optic systems. One of the sampling plug-ins that fits the scope, as well as the vendor's general-purpose 11800 series introduced less than a year ago, is a unit with an unprecedented 40-GHz bandwidth. Another sampling plug-in is an optical-to-electrical converter.



Several features distinguish the CSA 803 from the 11800 series. The CSA triggers on 10-GHz waveforms through use of an internal prescaler. You can also order the scope without the prescaler, in which case it will trigger on 2.5-GHz signals. Firmware features work with the unit's touch-sensitive color display to facilitate noise and jitter measurements based on "eye diagrams." In addition to constructing histograms, the unit lets you create and edit templates on its screen. You can store the templates in nonvolatile RAM and use them to determine whether particular signals fall within or outside your spec. From approximately $31,000.

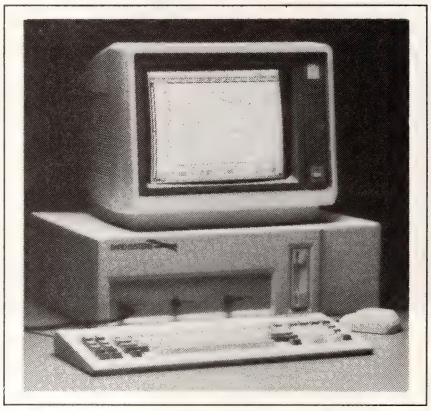
Tektronix Inc, Box 1700, Beaverton, OR 97077. Phone (800) 835-9433. **Circle No. 438**



Pocket Computer That Runs Interpreted C

The PB-2000C is a pocket computer the size of a large pocket calculator. The unit, which consumes 90 mW supplied by three lithium batteries, contains a C-language interpreter, and with the addition of ROM cards, can contain Prolog and Basic interpreters as well. The computer's 32k bytes of RAM are expandable to 64k bytes. With the addition of either of two expansion units, which contain RS-232C ports, you can upload your programs to a mainframe or workstation. One of the expansion units also contains a single-sided, 320k-byte, 3½-in. floppy-disk drive, and both contain Centronix parallel interfaces. The vendor offers a small character printer and a 4-color pen-plotter as accessories. $349.95.

Casio Inc, Box 7000, Dover, NJ 07801. Phone (201) 361-5400. FAX 201-361-3819. TLX 642754.
Circle No. 439



PC-Based Arbitrary Waveform Generator

The R4050 10-MHz arbitrary waveform generator includes a PC. A

built-in waveform library includes noisy, decaying, and full-wave rectified sine waves, sine waves with swept-frequency amplitude modulation, and a 50% amplitude-modulated carrier. The unit also produces standard sine, square, triangle, pulse, and white-noise waveforms. The generator uses a 12-bit DAC and stores waveform descriphtions as long as 16,000 points. Output modes are continuous, sweep, and burst; trigger modes are internal, external, and gated. You can control the points at which a waveform starts and stops and adjust waveform amplitude from 1 mV to 10V p-p. $4995.

Rapid Systems Inc, 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX 206-548-0322.

Circle No. 440

50/100-MHz, 240-Channel State/Timing Analyzer

The 5500, a logic analyzer intended to meet the needs of most users, can include from 48 to 240 channels that perform state or timing analysis at 50 MHz. The 50-MHz state-analysis capability is more than adequate for the fastest 32-bit processors currently available. Through multiplexing, which halves the number of channels, the instrument can perform timing analysis to 100 MHz. The self-contained unit includes a command-entry keyboard, whose layout is similar to that of an IBM PC keyboard, and a pair of 3½-in. floppy-disk drives. You can store setup information as well as data on disk. The unit stores 12k samples/channel at 100 MHz, captures 4-nsec glitches, and time-stamps unrelated samples with 10-nsec resolution. The triggering has 14 decision levels. $16,500 with 48 channels.

Marconi Instruments Inc, 7570 E Redfield Rd, Scottsdale, AZ 85260. Phone (800) 223-4143; in AZ, (602) 998-9294. FAX 602-998-9112. **Circle No. 441**

CIRCLE NO 12

DREAM METER.
mA
FRONT
BACK
80% SMALLER MOVEMENT, 66% FEWER PARTS.
Selco's core-magnet meter gives you the design features you've always wanted in an analog instrument, but were never able to get.
Like dramatically reduced total volume, improved reliability, and accuracy of ±1.5% of full scale.
Advanced Movement
Instead of a bulky magnet surrounding the coil, a powerful, compact magnetic core goes inside the coil.
Superior design, with taut band suspension, makes an overall simpler mechanism. And that means fewer failures and longer service life.
Range of Models
Selco's Dream Meter comes in four sizes, each with back-of-panel and front-of-panel mounting options. A wide selection of masks and bezels, too.
Both AC and DC versions are available, with ranges as low as 50μA and as high as 600V. All conform to BS89:1977, IEC51, and USA Standard ANSI C39.1-1972.
Marking Services
Custom marking can be obtained in one to four weeks. Mail or fax your sketch and we'll convert it to a meter face, color and all. Attractive prices with OEM discounts.
For complete details and quotations contact Selco today. We'll make your dream come true.
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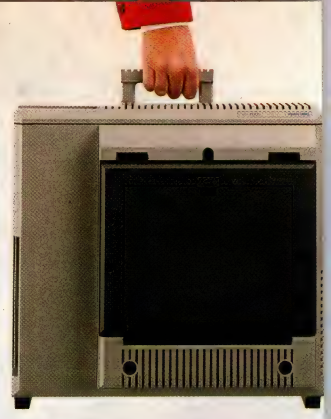
CIRCLE NO 13

HIGH-SPEED HARDWARE ANALYSIS MODULES: THE NEWEST PAYOFF TO YOUR PRISM INVESTMENT.



Visualize a logic analyzer that not only acquires microprocessor state and timing data, but adds emulation capabilities... real-time performance analysis...high-speed timing for hardware analysis...and more—all usable in precise, time-correlated combination. All configurable to your needs.

That's the visible edge of the Prism 3000 Series from Tektronix.

Start with up to 96 channels and the exceptional resources of Prism's 8/16/32-bit microprocessor integration modules.

You can view 200 MHz timing and 8K of state data per channel,

(Above, left) Real-time performance analysis as displayed on the Prism color monitor. (Left) The Prototype Debug Tool provides easy access to microprocessor control and debug functions, including the ability to set hardware and software breakpoints, and to patch registers and memory.

The new dimension of integrated analysis.

MPM/MPX Module	Microprocessor control Real-time performance analysis 200 MHz hardware analysis 8K deep state analysis Multiple Microprocessor support
HSM Module	2 GHz hardware analysis 300 MHz state analysis 1.5 ns glitch capture 12K transitionally-stored memory (up to 120K effective memory)

Now, just months after introduction, Prism breaks *new* barriers with a module specifically designed for hardware analysis—for detecting glitches, metastability, and the other common problems of state machines, busses, and sequential logic.

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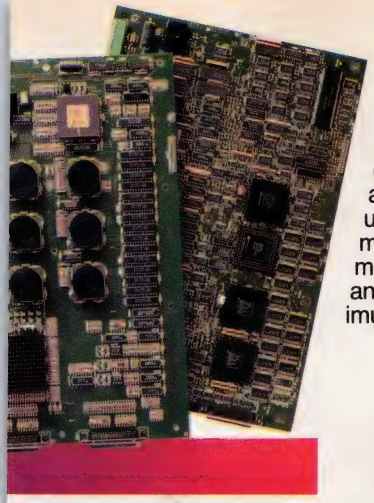


(Left) Prism microprocessor and hardware analysis modules are user-installable in minutes. These application modules can be configured in any combination, up to a maximum of ten cards per system.

all time-correlated and integrated on the same display. Set up state and timing sections to cross-trigger, synchronize and arm each other, so you know exactly when and in what time relationship events occur.

Push beyond microprocessor observation into microprocessor *control*.

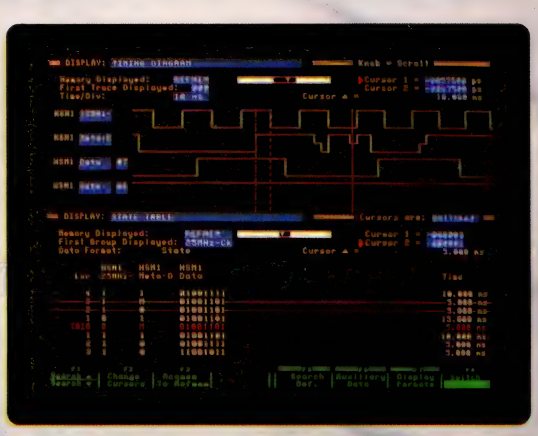
With its unprecedented Prototype Debug Tool, Prism lets you easily set breakpoints, patch registers and memory, restart the system —all without an emulator's intrusiveness.

Use real-time performance analysis to get a true, non-statistical view of system performance.

Designers of embedded control systems will especially benefit from histograms of uncompromising accuracy.

Now, with Prism's HSM high-speed hardware analysis module, you can add capabilities like 2 GHz timing and 300 MHz state analysis—and use these tools in tight time-correlation with other Prism modules.

(Below) The Prism HSM's dual threshold mode triggers on and displays a metastable condition. Middle thresholds are displayed as "M" in the time-correlated state table. Cursors measure the setup time violation that caused the metastable state.



Detect race conditions, setup and hold time violations, and glitches as small as 1.5 ns. Switch to dual threshold or digitizing modes to get a quick look at intermittent problems like ringing or undershoot.

Memory constraints are virtually eliminated: the HSM's 12K of transitionally-stored memory offers the equivalent of as much as 120K of conventional memory!

Choose from a stand-alone Prism, expandable mainframe-and-monitor, even a portable model with fold-up flat panel screen.

Features like autoload, split-screen displays, smooth scrolling and on-line help make Prism refreshingly simple to learn and use.

The clincher? You can step into this new generation of logic analyzers at prices starting at $8600.

Call 1-800-426-2200 for our free video demo and literature packet. For a hands-on introduction, call your Tek sales engineer soon.

Circle 103 for Literature
Circle 104 for Sales Contact

Tektronix
YOUR VISIBLE EDGE

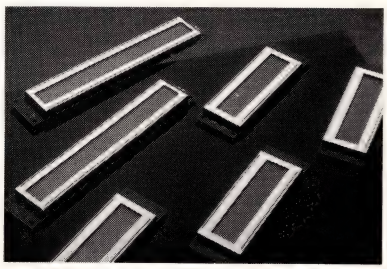
News from Philips

THE COMPLETE COMPONENT COMPANY

Philips Components
5600 MD Eindhoven
The Netherlands

Dot-matrix LCD modules now available from European supplier

Philips Components is now the first European supplier of six industry-standard dot-matrix LCD modules. The modules of the LTN221R/F-10 family, which extend the company's existing range, come ready-assembled with an integral controller on a printed-circuit board, and require only a single 5 V supply. They suit general-purpose applications including industrial, telephony, and EDP.



The LTN221R/F-10 family of dot-matrix LCDs is now available from Philips Components.

The LTN221R/F-10, LTN222R/F-10 and LTN242R/F-10 display two rows of 20,24 and 40 characters respectively, with a character size of 5 by 7 dots, plus cursor. Each type comes in reflective (suffix R) and transflective versions (suffix F). The transflective versions have optional green backlighting.

All modules have an integral microcontroller with a 160-character ROM, and 8-character RAM. The microcontroller accepts 4- or 8-bit parallel data, and has an extensive instruction set that includes display clear, cursor home, display on/off, cursor on/off, character blink, cursor shift and display shift.

Circle 331

New Plumbicon® tubes combine high performance with portability

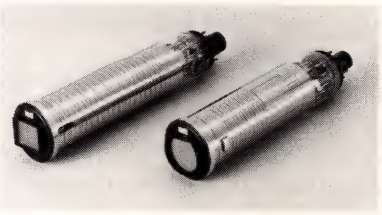
Philips Components is now supplying two new 2/3" Plumbicon® camera tubes which bring high-performance quality and portability to outside broadcast, industrial and educational applications.

One of the types – the XQ3477 – is the first tube to combine electrostatic focusing and electrostatic deflection. This reduces power consumption to less than 0.3 W per tube, which in turn reduces the requirement for weighty batteries. This feature makes the tube especially suitable for portable Electronic News Gathering (ENG) cameras.

The other new tube – the XQ3487 with magnetic focusing and electrostatic deflection – brings excellent resolution uniformity to professional Electronic Field Production (EFP) and ENG cameras.

The XQ3477 and XQ3487 have a tube length of 8.75 cm and 9.35 cm, respectively. Both tubes have a useful target area of 6.6 x 8.8 mm and exhibit a peak spectral response at 500 nm. Sensitivity for monochrome tubes is typically 320 A/lm. For red, green and blue channel tubes sensitivity is 100 A/lm, 135 A/lm, and 36 A/lm, respecitively.

Plumbicon® is a registered trade mark.



Leading the field in ENG/EFP tubes, the XQ3477 and XQ3487 combine quality and portability.

Circle 332

Highly-integrated 68000-compatible processor runs at 15 MHz

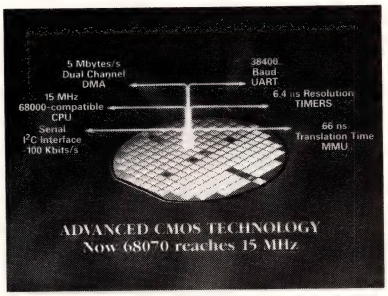
Philips Components announces a 15-MHz version of the company's highly integrated 68000-compatible SCC68070 CMOS microprocessor. The IC has a 5 Mb/s 16/32-bit two-channel DMA (direct memory access) controller, MMU (memory management unit), serial I²C bus, RS-232 interface and three counter/timers. The processor has a minimum instruction time of only 450 ns.

The circuit is fully compatible with 68000-family processors. It allows rapid development of new versions of existing 68000-based systems, while cutting design

ICs □ SEMICONDUCTORS □ DISPLAY COMPONENTS

Philips Components

costs, board space and power requirements. The SCC68070 can be used in applications ranging from personal computers and interactive compact disk stations to embedded controllers and industrial man-machine interfaces.



The 15-MHz SCC68070 microprocessor is ideal for battery operated or low power applications

The processor can address up to 16 Mb, with an MMU allowing it to perform multiprocessing and multitasking. The I²C bus connects the IC to a wide range of peripheral ICs, including DTMF generators, LCD drivers, extra memory, and clock calendars. The RS-232-C serial link eliminates the need for external components to perform serial-to-parallel and parallel-to-serial conversions.

The SCC68070 features enhanced bus-error handling similar to that of the 68010. Three on-chip 16-bit counter/timers reduce the need for external logic ICs; they can be used to provide an accurate time-reference clock, an event counter, and other timing functions.

The SCC68070 works in OS-9, GEMDOS and Unix environments, and can run multitasking kernels such as PSOS and VRTX. It is not only supported by companies recognized as specialist in the emulation field, but also by Philips' Single Board Emulator (SBE) and Standalone Development System (SDS) for in-circuit emulation. Philips also provides PC-compatible software tools, including assembler, C complier and linker, and symbolic C-language debugger.

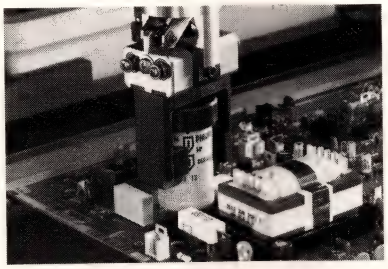
The SCC68070 consumes typically 6.5 mA/MHz in normal operating mode, with a consumption of about only 100 mA at 15 MHz. It comes in an 84-pin PLCC or 120-pin QPF (Quad Flat Pack).

Circle 333

New snap-in electrolytic capacitors with high volumetric efficiency

The new 056/057/058/059 series of non-solid electrolytic capacitors from Philips Components have twice the CV product per unit volume, and come with snap-in printed-board connections for efficient automated assembly. The devices are ideal for use in SMPS units in industrial and professional applications.

The 056/057 types offer a capacitance range of 47 µF to 1500 µF with a temperature range of −40°C to +85°C, while the 058/059 series offer values from 33 µF to 47000 µF specified up to 105°C. Rated voltage range (U_R) is 10 V to 400 V for all series.



Snap-in electrolytic capacitors are ideal for robot insertion.

Circle 334

High-power microwave CW transistor for satellite links

Providing 50 W continuous-wave power at 1.6 GHz, Philips Components' PXB16050U microwave power transistor delivers the highest output power yet for satellite links in INMARSAT and similar systems. The npn silicon planar epitaxial transistor works in common-base class C narrow-band amplifiers, and is suitable for voice and data communications for ships, aircraft and earth stations. An interdigitated emitter structure leads to a collector efficiency as high as 52%, and a low thermal resistance reduces junction temperatures for increased reliability.

The PXB16050U brings high-power output to microwave satellite links.

Input and output prematching circuits facilitate design of external circuitry and help avoid hot spots.

The transistor operates from a 28 V supply, and has a typical power gain of 9.5 dB. The thermal resistance is a low 1.5 K/W from junction to mounting base.

The transistor comes in an FO-91 metal-ceramic flange package.

Circle 335

PASSIVES □ PROFESSIONAL COMPONENTS □ MATERIALS

PHILIPS

PHILIPS

Drill of the year.

When *Popular Science* reviewed new power tools, many were good. In fact, even great. But one of them stood out above all the others. The Porter-Cable Model 9850. A professional cordless driver/drill—driven to perfection by a rechargeable battery from Gates Energy Products.

What does it take to be the best? Quite simply, pound for pound the 9850 delivers more work per charge than any other cordless drill of the same size.

Innovation is the key to the 9850. It starts with a powerful custom-designed 12-volt battery pack from Gates. Thanks to patented Gates technology, each full-size nickel-cadmium GEMAX™ cell is selected and graded to the highest performance rating possible.

Add the increased power of the world's first cordless tool motor ever made with Magnequench® rare-earth magnets—and the result is higher torque with less battery drain. In the end, a drill that drills larger holes and drives larger screws on 20% less energy

MAGNEQUENCH® is a registered trademark of the Delco Remy Division of General Motors.

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than other cordless drills of the same size.

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CIRCLE NO 80

PC-based single-board computers invade embedded systems

New μPs have extended the IBM PC's architecture far beyond the original personal computer's design. You can now choose from a wide range of hardware and software products that let you use PCs as low-cost development tools and exploit this family of architectures in your embedded-system designs.

Steven H Leibson,
Senior Regional Editor

The introduction of the μP in the early 1970s standardized processor architectures and instruction sets for most embedded-system designs. Single-board computers based on these μPs quickly followed each chip introduction, but board vendors avoided standardization beyond backplane bus structures. As a result, software developed for embedded systems was custom built for each single-board-computer architecture. Even something as simple as an existing serial-port driver routine usually couldn't be reused on new hardware without some revision. And if you needed more performance from a single-board computer to upgrade a product, you often had to rewrite your code to accommodate yet another board-level architecture. When the original μP ran out of horsepower, you'd have to rewrite your code using an entirely new instruction set.

Single-board computers based on the IBM PC's architecture have completely changed this situation.

Several μPs with 8-, 16-, and 32-bit data buses and clock rates as fast as 33 MHz can run PC code. This wide processor selection simplifies price/performance tradeoffs for embedded systems and eases the upgrade of existing products. Huge worldwide PC sales volumes have driven the prices of PC mother-board ICs into the ground—a condition that single-board-computer vendors have been quick to exploit. So you can now build economical embedded systems around PC-based single-board computers.

By standardizing the circuitry and software drivers for standard I/O devices, such as video adapters, serial and parallel ports, and floppy- and hard-disk controllers, the extended PC architecture (that of the PC, PC/AT, and 80386-based machines) frees you from the need to develop the low-level software that makes your hardware function and lets you focus on code that is specific to your embedded-system application. In addition, PC-based single-board computers let you use virtually any high-level language for software development. More com-

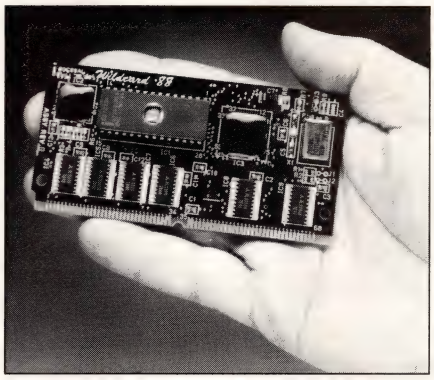
PC-based single-board computers let you create diverse embedded systems using the vast array of software tools available for the PC. Embedded systems shown at the top of the picture (from left to right) are the System/90 signal-analysis workstation from Rockland Scientific (Rockleigh, NJ), the Omninote desktop-communications system from Telautograph (Los Angeles, CA), and an automated IC die bonder from Hughes (Carlsbad, CA), all of which incorporate PC-based single-board computers from Ampro.

pilers are available for the IBM PC than for any other computer system on Earth. Because of intense competition, these compilers generally cost far less and do more than equivalent products for other computers. Consequently, you can get more reliable code with less effort and at a lower cost by embracing the PC's architecture for embedded-system designs.

Get any I/O board you need

Early adopters of the PC architecture simply bolted clone mother boards into their systems. As the PC became more and more successful, a huge expansion-board industry developed around the PC's bus. You can now get a mind-boggling array of I/O boards for the PC and PC/AT buses. The selection includes network controllers for many popular LANs, analog input and output boards, a wide array of video controllers and frame grabbers, digital I/O boards, disk and tape controllers for virtually any mass storage peripheral you might need, stepper-motor and relay controllers, modems, and even facsimile cards. This wide variety lets you configure a hardware system that exactly meets your embedded-system needs with just a bit of research.

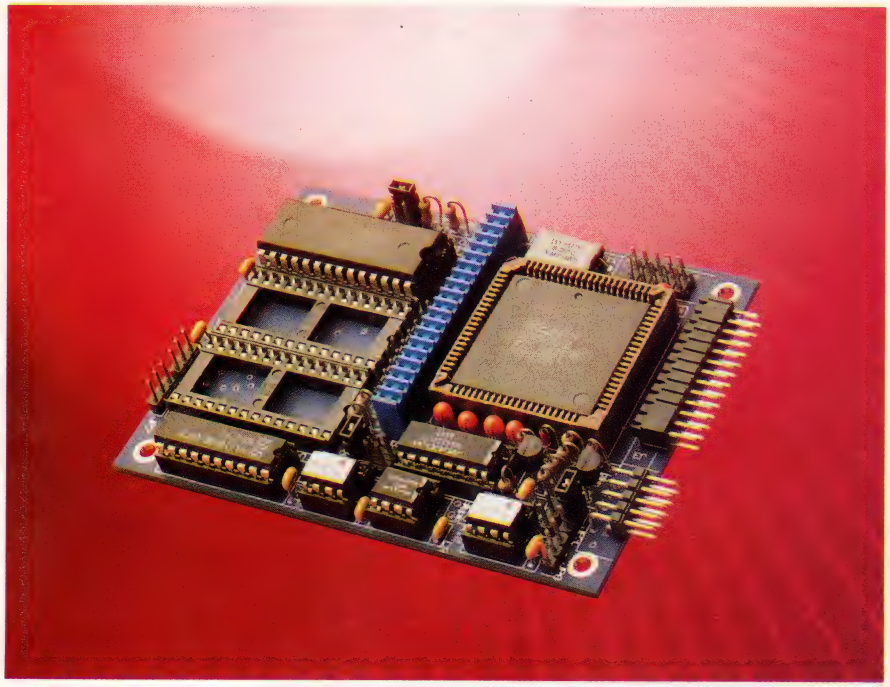
Although the PC's architecture gives you many choices, pressing mother boards into service for embedded-system designs creates a few problems as well. Conventional PC mother boards are fairly large because they have to accommodate the footprint and expansion-card slot pitch that IBM defined in its original PC and PC/XT machines. In 1988, Intel announced the Wildcard-88 to counteract this size problem. The Wildcard-88 is a $50 (1000) module that puts the entire circuitry of a PC's mother board on a 2×4-in. card.



Surface-mount and chip-on-board technologies shrank Intel's Wildcard-88, the functional equivalent of a PC mother board, down to a card measuring 2×4 in.

However, mother boards aren't always suitable for embedded applications. Most clone mother boards and the Wildcard-88 offer only keyboard and speaker ports; you must plug additional cards into the mother board's expansion slots to add serial and parallel ports, video and disk controllers, or other types of I/O capabilities to your system. In addition, most clone mother boards are designed for the relatively benign environment of the business desktop. Vendors often don't specify temperature and shock ratings for these mother boards, thus making them even less attractive for embedded-system applications.

Recognizing a ready-made niche market, several single-board-computer vendors took advantage of the high-density, low-cost PC mother-board chips now available from the semiconductor manufacturers to produce PC-based single-board computers for the embedded-systems market. These computer boards fuse the PC's mother-board circuitry with sufficient memory and I/O resources to provide embedded-systems designers with true single-board solutions. Several such single-board computers appear



By shedding unnecessary circuitry, near-PC single-board computers such as this 3×4-in. MC-2N card from Basicon can fit into extremely small volumes.

Early adopters of the PC architecture simply bolted clone mother boards into their systems.

in **Table 1.** They offer you a wide range of μPs, clock speeds, memory, I/O ports, and price; yet all run PC-based software, so you can move from one level of performance to another or cut costs by picking a different single-board computer while leaving your code unchanged.

Some of the single-board computers listed in **Table 1** support the PC's expansion-bus structure; others support alternative buses. Some single-board computers support multiple expansion buses. For example, Ampro has developed a line of I/O and memory cards it calls Minimodules. These cards plug directly into connectors on the company's Little Board line of PC-based single-board computers, thus they require no backplane. Ampro also offers two methods for adding PC bus slots to a Little Board system. Its $47 Stackplane plugs into a Little Board single-board computer and adds one PC bus slot to your system. If you need more slots, you can use the company's 2-slot Minibackplane/PC, which costs $38 ($65 for the Minibackplane/286), or its $31 PC bus backplane adapter, which lets Little Boards drive multislot, passive PC bus backplanes.

Many PC-based single-board computers also offer nonPC fea-

Table 1—Representative single-board computers based on the IBM PC architecture

Manufacturer	Model number	μP	Clock rate (MHz)	RAM (bytes)	Bus	Keyboard port	Video port	Speaker port	Parallel port(s)	Serial port(s)	Size (in.)	Base price	Comments
Ampro	Little board/PC	V40	7.16	256k to 768k	PC (with adapter) and minimodule	Yes	No	Yes	Printer	Optional	8x5.75	$496	Memory, ROM disk, and I/O modules available.
	Little board/286	80C286	12 or 16	512k to 2M	PC/AT (with adapter) and minimodule	Yes	No	Yes	Optional	Optional	8x5.75	$990	Memory, ROM disk, and I/O modules available.
Citadel	286XP	80C286	16	640k to 4M	PC/AT or CIMBUS	Optional	Optional	Yes	24 bits	2	8.6x5.14	$1995	Floppy-disk and SCSI ports. 512k-byte ROM disk. 2 RTCs. Wide operating-temperature range. Rugged package.
	286LP	80C286	16	640 to 2M	PC/AT (with adapter) and SBX	Yes	VGA/ LCD	Yes	Printer	2	8x9	$1195	512k-byte ROM disk, RTC.
Computer Dynamics	CPU-XT	8088 or V20	4.77/9.54	256k to 640k	STD	Yes	Mono/ CGA	Yes	Printer	2	6.5x4.5	$995	Watchdog timer, floppy- and hard-disk interfaces.
Gespac	Gespac AT	80286	10	512k	G64	No	No	No	No	2	4x6.5	$1495	EGA/keyboard and disk-controller cards available.
Megatel Computer	Quark/ PC+	V40	8 or 10	256k to 768k	PC (with adapter)	Yes	Optional	Yes	Printer	Optional	4x6	$295	Optional SCSI and floppy-disk ports, RTC, and ROM disk.
	Quark/ PC II	803865X	16	1M to 4M	PC/AT (with adapter)	Yes	Mono/ GCA/ EGA/ LCD	Yes	Printer	2	4x6	$1395	SCSI and floppy-disk port, RTC. Optional ROM disk.
Mircro Linear Controls	MLC-XT	8088	4.77/7.15	256k to 512k	PC and Wildcard	Yes	No	Yes	No	No	6.4x4.2	$660	Includes RTC and solid-state disk card.
Micro/sys	ECX-188	80188	6	64k to 512k	Priprietary	No	No	No	32 bits	2	8.8x5.8x1.5	$740	Built into a metal enclosure.
Octagon	8500	V20	4.77/7.15	128k to 256k	STD	Yes	No	No	Printer	2	4.5x7	$795	Watchdog timer, RTC.
	9500A	V25	8	128k to 512k	STD	Keypad	Alpha	No	24 bits	2	4.5x7	$545	Floppy-disk port. Optional RTC.
Ziatech	ZT8808/9	V20	5 or 8	8k to 264k	STD	No	No	No	Printer	2	4.5x6.5	$595	Industrial temperature versions available.
	ZT8816	V50	8	576k	STD	No	No	No	DMA port	2	4.5x6.5	$1195	
	ZT8832	V40	8	32k to 256k	STD	No	No	No	24 bits	2	4.5x6.5	$785	DOS multiprocessor slave board.
	ZT8910	80386SX	16	1M to 4M	STD-32	Yes	No	Yes	Printer	2	4.5x6.5	$2700	Hard-disk port, 2 RTCs.

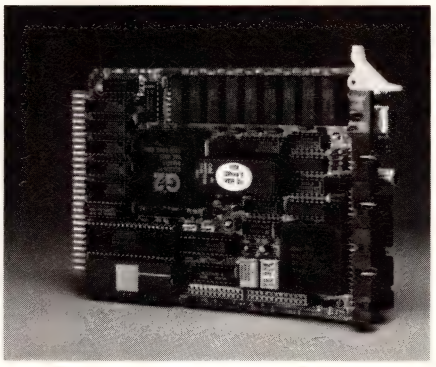
Note: Printer ports may also be used as general-purpose, 8-bit parallel output ports. (Some are bidirectional.)

tures specifically designed for embedded-system applications. For instance, several of the single-board computers listed in **Table 1** include watchdog timers to ensure that unexpected events, power surges, or static discharges don't send your unattended program out to lunch for good. In addition, many PC-based single-board computers incorporate nonvolatile semiconductor memory in place of a PC's floppy and hard disks. These "solid-state disks" benefit both low-cost and rugged applications.

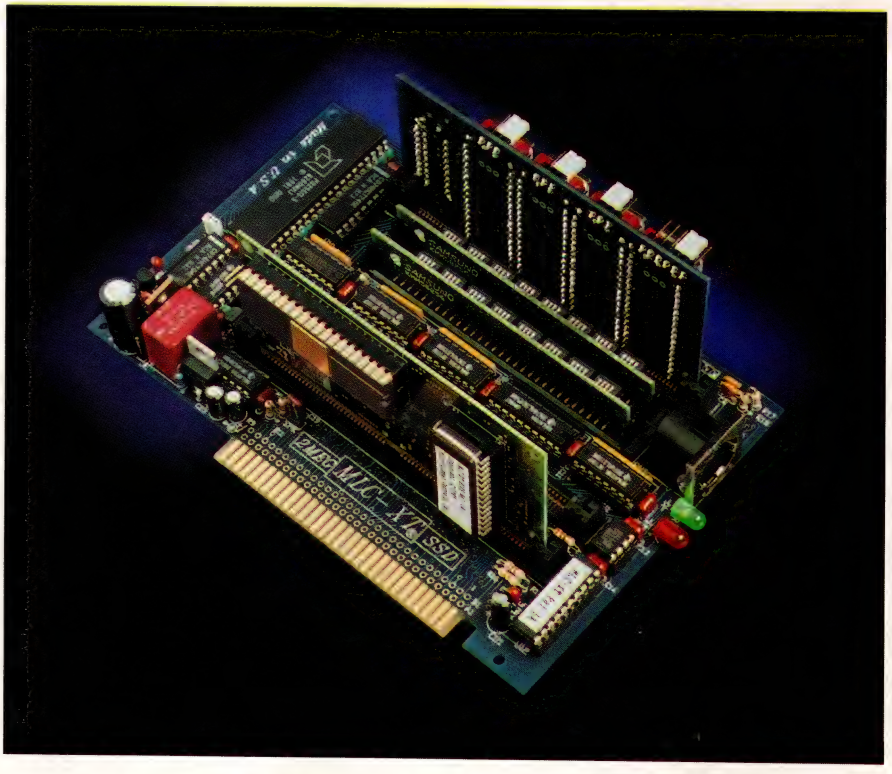
You may not want to incur the expense of a disk drive if you're designing a low-cost system, and if you are designing a product that must endure temperature extremes or physical shocks, you'll want to reduce the number of mechanical devices in your design to a minimum or eliminate them entirely to boost system reliability. Yet most versions of Microsoft's DOS, the most commonly used PC operating system, expect some sort of disk drive to be a part of the PC. As an alternative, some single-board-computer vendors offer EPROM and EEPROM as replacements for mechanical disk drives to meet these requirements of low-cost and ruggedness. (For more information on operating systems, see the **box,** "Operating systems for PC-based embedded systems.")

The MLC-SSD memory module from Micro Linear Controls is an excellent example of a solid-state disk for PC-based embedded systems. The card snaps into a slot on the company's MLC-XT single-board computer, which is based on the Intel Wildcard-88, and is included with that single-board computer. The solid-state disk card carries four 32-pin DIP sockets that together can hold as much as 1M byte of EPROM or flash EEPROM or 128k bytes of battery-backed SRAM. The board programs EPROMs and EEPROMs in place, and the company provides two utility programs, SSFORMAT and SSXFER, that respectively let you format and transfer hidden system files to the solid-state disk. You can copy normal DOS files, such as your executable program and data files, to the solid-state disk with the conventional DOS COPY command. To boot from the MLC-SSD memory module instead of a floppy disk, leave the floppy drive open, have a nonbootable disk in the floppy drive, or leave the floppy controller and drive out of the system entirely. The MLC-XT's BIOS ROM detects the absence of a bootable floppy disk, reassigns the solid-state disk to drive A, and boots from solid-state memory instead. SSFORMAT lets you make the solid-state memory appear to be as many as eight disk drives.

All of the single-board computers listed in **Table 1** include BIOS ROMs that mate DOS-based software to the single-board computer's



The 2-board sandwich comprising the CPU-XT lets Computer Dynamics squeeze a complete PC-based single-board computer, including a hard-disk interface, into the STD-board format.



Buses within buses place the Intel Wildcard-88 and a solid-state disk card on the MLC-XT single-board computer from Micro Linear Controls. An entire PC and solid-state disk thus occupy only a small, PC bus-format half card.

PC-based single-board computers provide embedded-systems designers with true single-board solutions.

hardware. BIOS-level compatibility is a key element in allowing DOS software to work in embedded-system applications. Another element is hardware compatibility. A certain class of single-board computers, "near PCs," dispense with hardware-level compatibility—except for the μP, which must be able to run 8088 μP machine code for the single-board computer to be considered "nearly" a PC. A repre-

Operating systems for PC-based embedded systems

Every PC uses some kind of operating system, but that's not always the case for embedded applications. You don't always need an operating system for ROM-based designs. However, single-board computers with ROM disks do need an operating system because they emulate the operation of a PC. Microsoft's DOS is the common operating-system choice for PCs. However, until very recently you couldn't run Microsoft DOS from ROM because ROM code and data spaces are thoroughly intermixed. Code runs well in ROM, but program variables, by definition, present something of a problem if you can't change them because they're burned in.

The growing number of portable, laptop, and pocket PCs prompted Microsoft to develop a version of DOS that could execute from ROM; however, this new version of Microsoft's operating system is equally suitable for embedded systems. The company recently announced that it is ready to negotiate a license with OEM customers for this ROM-executable operating system, which is compatible with version 3.21 of the company's DOS. The ROM-executable operating system requires only 15k bytes of RAM. The RAM-based version of Microsoft's DOS 3.21 requires about 50k bytes of memory.

Microsoft's ROM-executable operating system is a newcomer to the market. Several other vendors have offered ROM-executable, DOS-compatible operating systems for a while. One of those operating systems, Digital Research's DR DOS, can run from ROM because the vendor took special care to separate code and data. Ampro, one of Digital Research's OEM customers, ships a single-copy DR DOS license with each of its Little Board single-board computers. DR DOS 3.41 is compatible with Microsoft's DOS 3.3 and supports extensions to that operating system, including the LIM (Lotus/Intel/Microsoft) 4.0 expanded-memory specification and hard-disk partitions larger than 32M bytes. Digital Research will negotiate a license for its operating system with customers who want to build as few as 1000 units. A system builders' kit that includes the operating system and instructions for putting DR DOS in ROM costs $300.

If your embedded-system design requires the services of an operating system but doesn't have a disk drive or a ROM disk, you'll need some help to put that operating system into a ROM. Annabooks' $179 PROMKit offers one solution to this problem. The product essentially takes an entire bootable floppy disk (boot sectors, operating system, executable files, and data files) and transforms it into one data file, which you can then burn into a ROM. The PROMKit also includes instructions for adapting your hardware to use the resulting ROM as a disk drive.

Datalight also offers products that can help you put an operating system into a ROM. The company's $495 ROM-DOS is a clone of Microsoft's DOS version 3.2 but is designed to run in ROM. It requires about 29k bytes of ROM and uses about 5k bytes of RAM for system variables. The ROM-DOS package includes a miniBIOS that works with ROM-DOS and supports a serial port as the system console. Datalight charges $3 to $25 for each copy of ROM-DOS you ship in your systems, depending on your unit sales volume.

If your application doesn't require an entire operating system with resident and transient commands and if you write your application program using Microsoft's C compiler, Datalight's C-thru-ROM might satisfy your operating-system needs. The $495 package provides a kernel that includes start-up code and DOS-like I/O routines for embedded-system programs written in Microsoft C. You use the Microsoft linker to combine your object modules with Datalight's run-time library routines to produce the final code, which is ready for placement in a ROM. C-thru-ROM also includes a remote debugger to help you troubleshoot software problems during development. Datalight charges a $2000 one-time royalty fee for use of its C-thru-ROM kernel in your production units.

sentative sample of such near-PC single-board computers appears in **Table 2.** You can save some money if you are willing to make your application code run on a near-PC board-level computer because you won't have to pay for all of the PC's mother-board and I/O circuitry.

Near-PC single-board computers won't run every DOS-based program, but they can run "well-behaved" DOS applications. For PC programs, the term "well-behaved" means that the application software must control the board's hardware through BIOS calls and never directly address the board's I/O ports. If you write your application code in assembly language, you can usually make your software behave properly, but if you use a high-level language compiler, you'll often take pot luck with I/O routines.

Shrouded in metal, the ECX Model 188 single-board computer from Micro/sys targets rugged applications and can run all PC software.

Tame your code

Unless you have the compiler's I/O source code, you won't know if a particular compiler generates well-behaved I/O code. To circumvent this problem, you could avoid the use of language statements that call library I/O routines and write your own I/O routines in C, Pascal, or another language du jour. But this technique severely reduces the advantages of picking the PC architecture in the first place. In lieu of the I/O source code, you could ignore the potential problems, write your program, and hope for the best. If problems do crop up—and they usually do—you can troubleshoot them, probably in fire-fighting mode. Your software quality-assurance people will probably

Table 2—Representative single-board computers based on "near-PC" architectures

Manufacturer	Model number	μP	Clock rate (MHz)	RAM (bytes)	Bus	Keyboard port	Video port	Speaker port	Parallel port(s)	Serial port(s)	Size (in.)	Base price	Comments
Basicon	MC-2N	V25	8	32k	Proprietary	No	No	No	21 bits	2	3×4	$349	8-channel analog comparator, 2 timers.
Computer Dynamics	CPU-188	80188	8 or 10	1M	STD and iSBX	No	No	No	24 bits	2	6.5×4.5	$350 (OEM)	12 counter/timers.
Vesta Technology	Micro88-8k	8088	4	8k to 32k	Proprietary	No	No	No	No	2	3×5.3	$169	$259 DEV88 board adds EPROM sockets and programmer.
	Tiny188	80188	8	1M	Proprietary	Keypad	LCD	No	No	2	3.94×6.3	$269	$259 DDS188 board adds EPROM and floppy-disk controller.
Ziatech	ZT8806/7	8088	5 or 8	128k	STD	No	No	No	16 bits	1	6.5×4.5	$350	RTC, 5 counter/timers.

Note: RTC = real-time clock/calendar

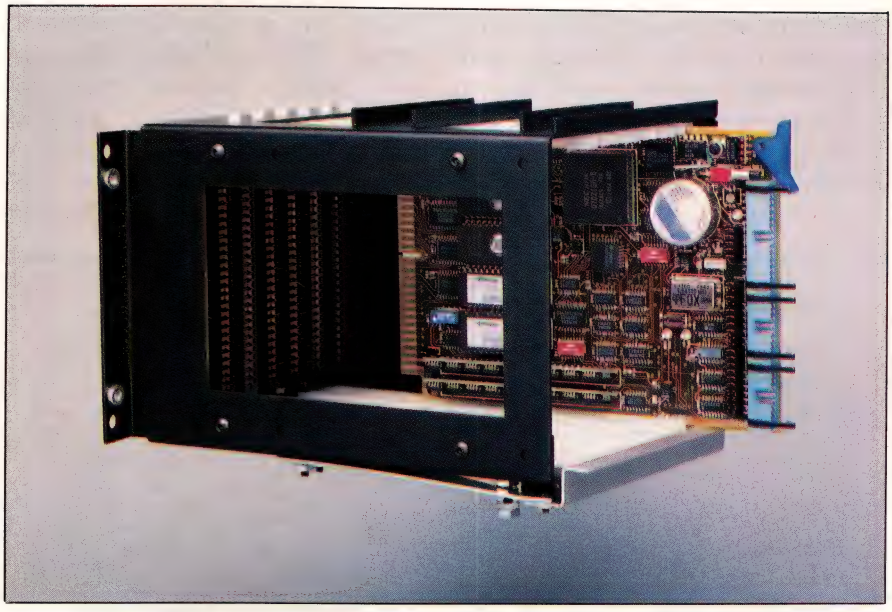
Near-PC single-board computers won't run every DOS-based program, but they can run "well-behaved" DOS applications.

boil you in oil for taking such a wrong-minded approach to software development in the first place.

Single-board-computer vendors sometimes offer their own development languages, which do generate well-behaved application code, as an alternate solution to this problem. For example, Vesta Technology offers versions of Basic, C, and Forth for its near-PC single-board computers. Similarly, Octagon Systems provides a Basic development system with its PC-based single-board computers. Octagon has added features that are targeted at control applications to its Basic dialect. These features include frequency measurement and pulse generation.

The near-PC single-board computers listed in **Table 2** and some of the PC-based boards do not incorporate solid-state disks and, therefore, cannot run executable DOS programs (EXE and COM files) directly. These boards generally have sockets for nonvolatile memory ICs, but you must use an appropriate compiler or a linker/locater program instead of ROM-disk software to put your code in ROM.

At least one compiler vendor—Lattice Inc—offers a PC-based compiler designed to help you completely eliminate DOS calls from your application code. The company's $900 ES86 C development system generates code for all PC-compatible μPs and, like all of Lattice's compilers, uses language function calls to activate I/O routines rather than relying on DOS INT (interrupt) calls. This approach gives you more freedom to tailor the compiler-generated, hardware-specific I/O code for your particular system. The ES86 package includes the source and object code for I/O drivers that work with the standard



PC-based single-board computers need not support the PC bus. This Ziatech ZT 8816 operates on the STD bus and makes the large number of STD-format I/O boards available to the embedded-systems designer.

PC I/O devices. You can use these drivers as guides to help you generate the proper I/O code for your single-board computer's I/O hardware if it differs from the standard PC circuitry.

Build your own BIOS

Most DOS-based native compilers rely on DOS for many I/O services and generate relocatable EXE files that won't run without help from DOS. For an embedded-system design, you may not be able to count on the presence of DOS to supply startup code and file-I/O services to your program. BIOS ROMs supplied with some PC-based single-board computers directly support DOS calls to circumvent the need for an operating system. If your single-board computer doesn't include such a BIOS ROM, you can create one yourself using either the $99 XT BIOSKit or the $199 AT BIOSKit from Annabooks. These two products provide you with the C source code you need to compile your own BIOS ROMs. You are free to add or delete services to these ROMs as needed. Annabooks charges a $2 production royalty fee for each XT BIOS ROM you ship and a $4 fee for every AT BIOS ROM shipped.

Several vendors offer products that let you circumvent the need for a BIOS ROM. For example, a $295 software-development package called Paradigm Locate from Paradigm Systems Inc helps you create stand-alone PC-based programs that don't require an operating system or a BIOS ROM. Paradigm Locate provides linking, locating, and DOS emulation services for application software written with Microsoft's C compilers, Borland International's C and Pascal compilers, Modula-2, or assembly language. Paradigm Locate's I/O libraries replace the corresponding run-time libraries of the compilers (assemblers don't generally have

Single-board-computer vendors offer EPROM and EEPROM as replacements for mechanical disk drives to meet low-cost and ruggedness requirements.

run-time libraries) and let you write the code necessary to link the single-board computer's hardware to your application software.

Similarly, FS Locate from First Systems Corp includes a locating linker, startup code, and DOS emulation for memory management, stream I/O, and other DOS run-time library routines. The $295 package works with all Microsoft and Borland compilers and includes instructions for using Microsoft's and Borland's numeric-coprocessor emulation libraries. Several other vendors also offer linker/locater packages for PC-based embedded-system development. Systems & Software's $395 Link and Locate ++ package accepts object files from Microsoft's C compiler and

For more information . . .

For more information on the PC-based embedded-system-development prodaucts discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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Phoenix, AZ 85069
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Sunnyvale, CA 94089
(408) 734-2800
FAX 408-734-2939
TLX 4940302
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Annabooks
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San Diego, CA 92128
(619) 271-9526
Circle No. 652

Basicon Inc
14273 NW Science Park Dr
Portland, OR 97229
(503) 626-1012
FAX 503-643-4686
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Borland International Inc
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Scotts Valley, CA 95066
(408) 439-1800
TLX 172373
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Citadel Computer Corp
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Amherst, NH 03031
(603) 880-6200
TLX 0258194
Circle No. 655

Computer Dynamics
107 S Main St
Greer, SC 29650
(803) 877-8700
FAX 803-879-2030
Circle No. 656

Datalight
17505 68th Ave NW, Suite 304
Bothell, WA 98011
(206) 486-8086
Circle No. 657

Digital Research Inc
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Monterey, CA 93942
(408) 649-3896
FAX 408-649-0750
TWX 910-360-5001
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First Systems Corp
2275 W Torrance Blvd, Suite 201
Torrance, CA 90501
(213) 328-6730
FAX 213-328-6835
Circle No. 659

Genesis Microsystems Corp
13300 E Sunset Dr
Los Altos, CA 94022
(415) 941-9002
Circle No. 660

Gespac Inc
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Mesa, AZ 85202
(602) 962-5559
FAX 602-962-5750
TLX 386575
Circle No. 661

Intel Corp
Box 58065
Santa Clara, CA 95052
(800) 548-4725
Circle No. 662

Lattice Inc
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Lombard, IL 60148
(312) 916-1600
FAX 312-916-1190
TLX 532253
Circle No. 663

Megatel Computer Corp
125 Wendell Ave
Weston, Ontario
Canada
M9N 3K9
(416) 245-2953
FAX 416-245-6505
Circle No. 664

Micro Linear Controls Inc
1713 Mt Pleasant St
Racine, WI 53404
(414) 639-1105
FAX 414-637-0859
Circle No. 665

Microsoft Corp
Box 97017
Redmond, WA 98073
(206) 882-8080
FAX 206-883-8101
TLX 328945
Circle No. 666

Micro/sys
1101 Grand Central Ave
Glendale, CA 91201
(818) 244-4600
Circle No. 667

Octagon Systems Corp
6510 W 91st Ave
Westminster, CO 80030
(303) 426-8540
FAX 303-426-8126
Circle No. 668

Paradigm Systems Inc
Box 152
Milford, MA 01757
(508) 478-0499
Circle No. 669

Systems & Software Inc
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Irvine, CA 92714
(714) 833-1700
FAX 714-833-1900
Circle No. 670

Vesta Technology Inc
7100 W 44th Ave, Suite 101
Wheatridge, CO 80033
(303) 422-8088
Circle No. 671

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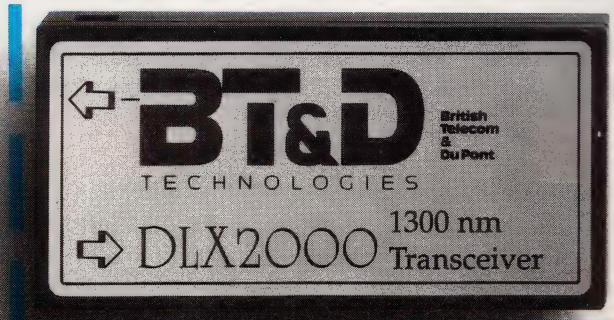

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TECHNOLOGIES

A New Direction in Optoelectronics.

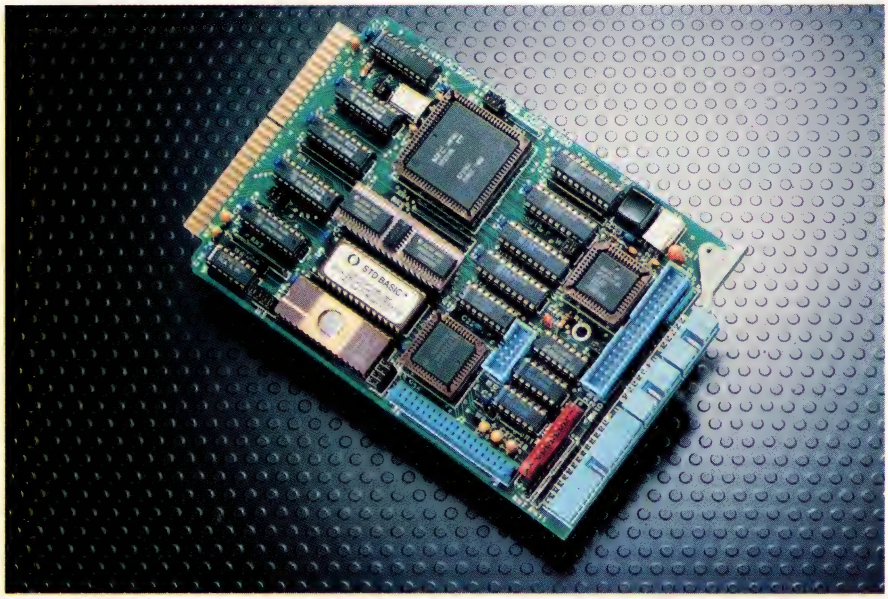
You may not be able to count on the presence of Microsoft DOS to supply startup code and file-I/O services to your embedded-system program.

macro assembler and produces executable object modules in Intel's object-module format, which Intel abbreviates OMF. Some in-circuit emulators can use OMF files to perform symbolic debugging. The product also includes startup code in source form and a book, *Writing ROMable Code in Microsoft C*.

Aldia Systems' $250 PC-Locate can convert any DOS EXE file into an absolute file for ROM-based operation. This approach frees you from having to use a particular compiler, but you won't be able to generate complete symbolic debugging information because that information is not present in EXE files. GeneLink, a linker/locater from Genesis Microsystems, accepts Intel and Microsoft OBJ and LIB files and produces absolute object files in Intel's OMF. In addition, the $495 package can generate DOS COM and EXE files for use on the PC. This feature is particularly important for programs created with Intel software-development tools that don't generate DOS files, but the company emphasizes that the product's speed makes it an attractive replacement for DOS-based linkers, too.

First Systems, Genesis, and Systems & Software also offer target-system debuggers that are closely coupled to their respective linker/locaters. Paradigm Systems offers an interface package that enables Borland's Turbo Debugger package to work as a remote debugger with programs linked by Paradigm Locate. Borland supplies the Turbo Debugger with its $250 Turbo Pascal Professional, $250 Turbo C Professional, and $149.95 Turbo Assembler packages.

These different approaches to creating and debugging programs for PC-based and near-PC single-board computers illustrate the level of development support you receive when you adopt the PC's architecture for embedded-systems design. With PC-based designs, lack of alternatives rarely forces you to develop your product in one particular way. In fact, in the PC environment, you usually have far too many choices, but you'd rather have too many than too few.



Some PC-based single-board computers, such as the Model 9500A from Octagon Systems, include languages tailored to single-board-computer-type applications. Octagon's Basic language is tailored to control applications.

Ultimately, deciding whether to use the PC architecture for an embedded system will depend on the classic engineering factors: price, performance, and development costs. Like any single-board computer, a board-level computer based on the PC's architecture drastically reduces your hardware-development effort, and the wide range of software-development tools available for the IBM PC lets you develop software in your favorite programming language with relative ease. And if you discover that your sales volumes are skyrocketing, you can always revisit your product's hardware design and employ the very same low-cost PC mother board and I/O chips used on your single-board computer to create a board that is tailored to your application. With this unprecedented hardware flexibility and software support, the extended PC architecture deserves serious consideration for your next embedded-system design. EDN

Article Interest Quotient
(Circle One)
High 509 Medium 510 Low 511

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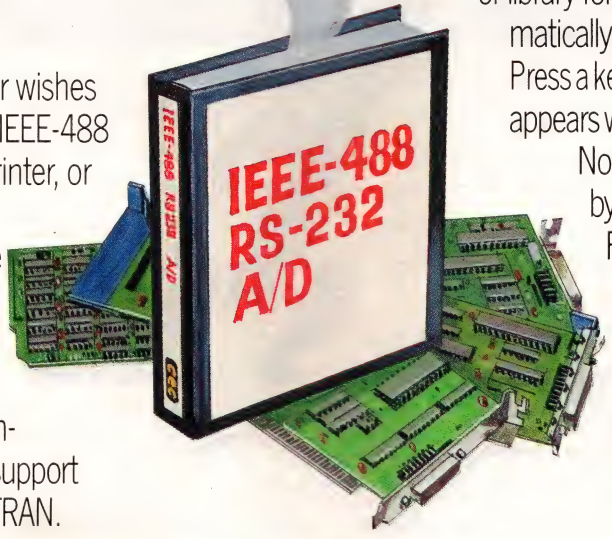

If your wish is for a custom program, CEC also offers software that writes '488 programs. Simply pop up our software over your program editor and select a control function or library for your instrument. Code is automatically generated from your choices. Press a key and the magic begins. The code appears where you want it in your program.

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For example, our 80C286 executes 8086 and 80286 16-bit code — representing the industry's largest base of installed software — at the industry-leading speed of 25MHz. You get industry-standard software with industry-leading throughput.

There's another key to processor selection: a growth path for the future. The 80C286 offers a wide performance range — from 12.5MHz to 16MHz through 20MHz and on to 25MHz — so you can migrate simply and smoothly when you need higher throughput.

Speed isn't the only issue, however. System requirements are becoming more and more complex with the need for multiple tasks and increased security. The 80C286 with its protected mode operation and multi-tasking capability keeps application software and data organized and secure.

Another measure of performance is durability — running faster longer. The 80C286's low power

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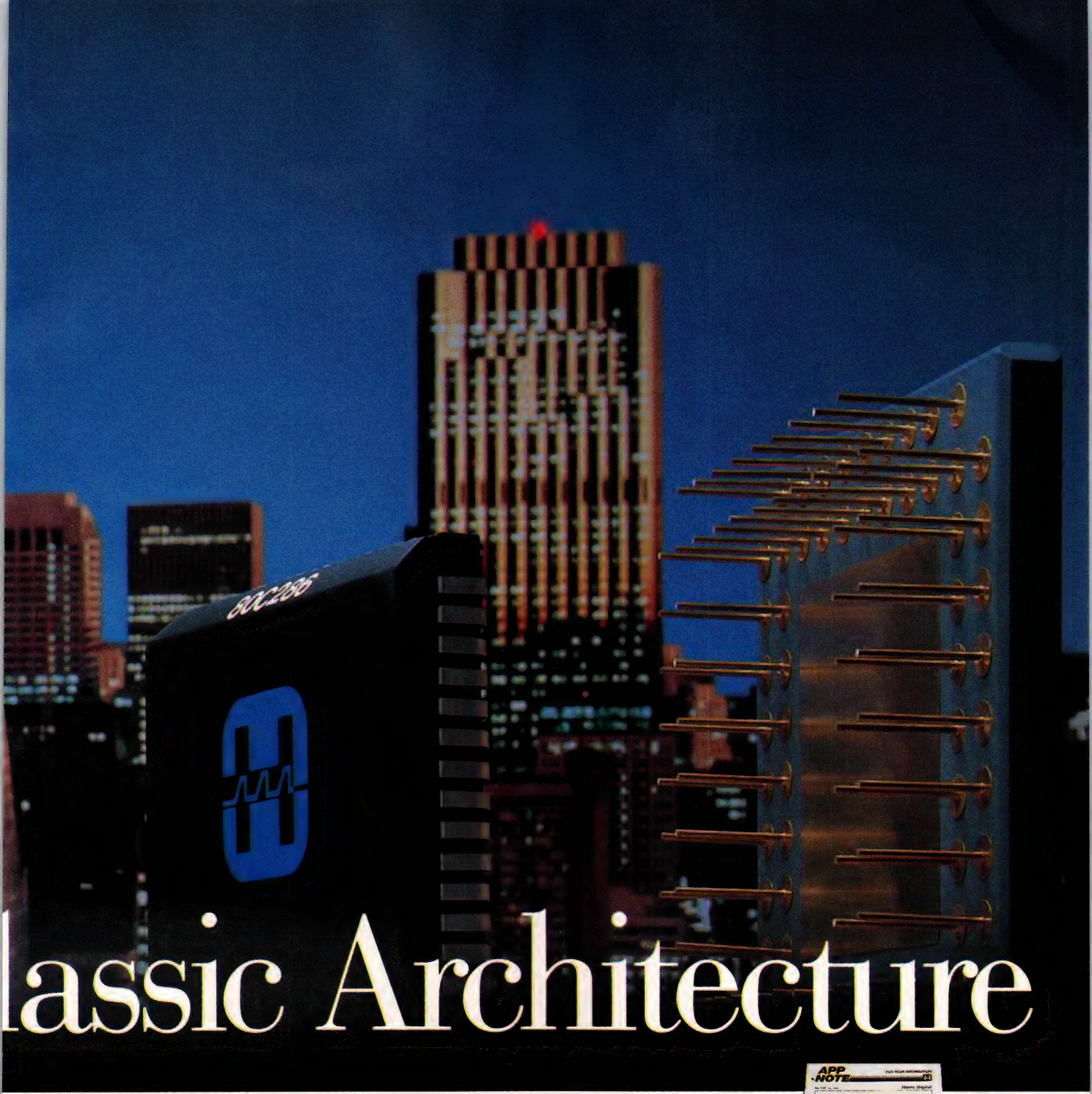
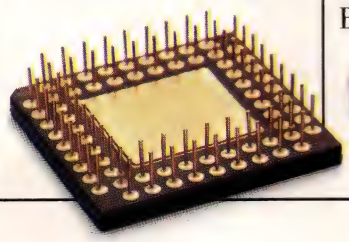


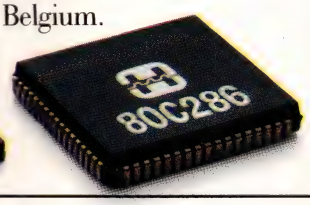
lassic Architecture

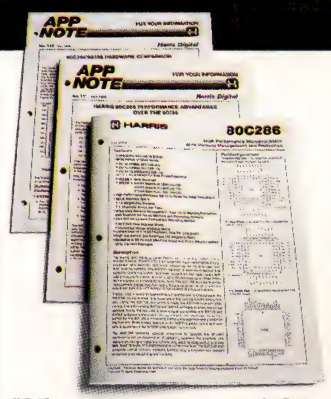
design assures that. No overheating. No reduced ambient temperature specification. No fans or heat sinks. Just reliable high-performance operation with low power dissipation — ideal for portable instrumentation or sealed enclosures for harsh environment applications.

Build your foundation for the future around proven architecture with existing software support and a path to performance upgrades. Call for our technical information outlining all the 80C286's advantages. For peak performance, move up to the fastest 80286 yet — the Harris 80C286.

Call (32) 2-246-2330 or contact Harris Semiconductor, Mercure Centre, Rue de la Fusee 100, 1130 Brussels, Belgium.







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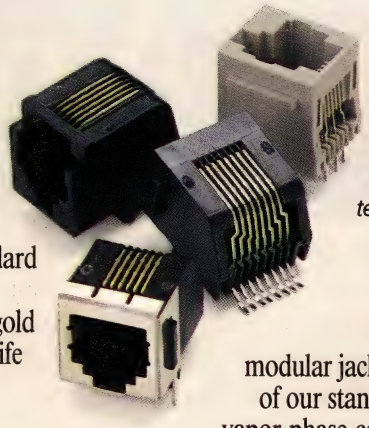
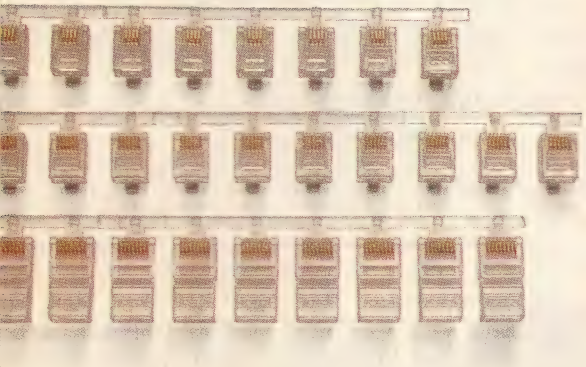


Shielded mod plugs in fully-loaded 6- and 8-position versions have insulation-piercing terminals. Shielded jacks in board-ground or panel-ground designs.

Or the surface-mount modular jacks. With all the features of our standard line in low-profile, vapor-phase-compatible modules that integrate easily with accepted processing, even robotic insertion.



Strip-form mod plugs allow termination with high-speed application tooling.

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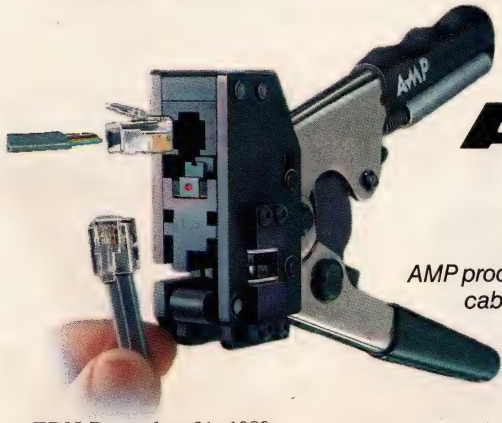
Call 1-800-522-6752 for literature on AMP Modular Connectors. AMP Incorporated, Harrisburg, PA 17105-3608.



AMP production hand tool cuts cable, strips cable jacket, and mass terminates loose-piece plugs.

AMP Interconnecting ideas

CIRCLE NO 84

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"When I was on the client side, I demanded sales results from my advertising dollars," says John Poturny, President of Poturny & Associates. "Today I'm on the agency side, and I expect the same for my clients — advertising that generates sales."

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"After running ads in EDN News Edition, our phones ring and proposal activity soars immediately for our military power supplies," says Fred Silver, Director of Marketing at Rantec, a division of Emerson Electric.

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John Poturny

Fred Silver

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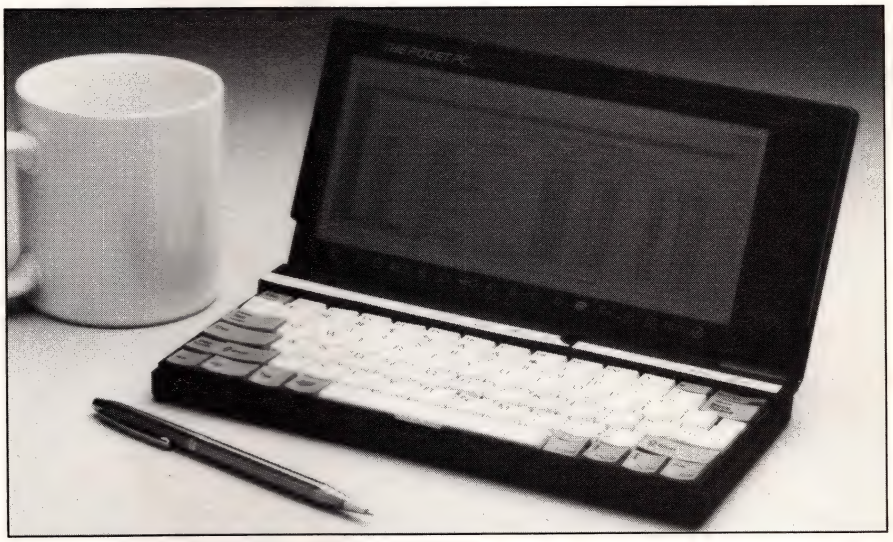
Pocket-size MS-DOS computer uses two standard AA batteries



The Poqet PC is a portable MS-DOS personal computer that can operate for 100 hours on two standard, AA-size batteries. The pocket-size computer measures 8.75×4.3×.9 in. and weighs approximately 1 lb. The unit features an 80-character×25-line monochrome nonbacklit LCD with 640×200-pixel resolution. The display supports IBM CGA and MDA modes, has an adjustable contrast and viewing angle, and automatically shuts down after 2 minutes. The computer also has a 77-key QWERTY keyboard with 12 function keys and an embedded numeric keypad.

Its I/O bus for peripheral expansion is compatible with the IBM PC/XT bus and an RS-232C port. The computer uses a 7-MHz 80C88 μP and has 512k bytes of RAM and 640k bytes of ROM. The ROM stores MS-DOS version 3.3, GW Basic, the BIOS, a virtual network architecture, and the company's PoqetTools utilities.

To transfer files from the computer onto a floppy disk that's compatible with desktop computers, a portable, battery-operated, 3½-in., 1.44M-byte floppy-disk drive that runs on four AA batteries is also available. The computer costs $1995; the disk drive costs $395.

Poqet Computer Corp, 650 N Mary Ave, Sunnyvale, CA 94086. Phone (408) 737-8100. FAX 408-720-8221. **Circle No. 702**

PC-based add-in card yields 33M-flops performance

The Spirit-30, an add-in card for IBM PCs and compatible computers, is based on the Texas Instruments TMS32C0C30 DSP μP and performs 33M flops. Benchmarks show that the board executes a 1024-point FFT in 3.1 msec, executes a 64th-order FIR filter algorithm in 4.67 μsec, and multiplies a 3×3 and a 3×1 matrix in 0.78 μsec. The board includes 128k bytes of 25-nsec static RAM that's dual ported between the DSP μP and the host's bus.

A daughter card allows you to add 512k bytes of static RAM. In embedded applications, you can also substitute EPROM for the static RAM. The board can transfer data over an 8-MHz IBM PC/AT bus, and it transfers data as fast as 2 MHz over faster host buses. It has six expansion connectors, which include a 37-pin universal host interface; a 60-pin, main-memory expansion bus; a 60-pin, peripheral-memory expansion port; a 50-pin, parallel I/O port; and two serial ports.

Software support includes the EDSP development package, which provides simulation and debugging capabilities for real-time, DSP μP applications. The board costs $2495; EDSP software costs $495. You can also purchase a DSP library for $295, or $985 if you need the source code.

Sonitech International Inc, 83 Fullerbrook Rd, Wellesley, MA 02181. Phone (617) 235-6824. FAX 617-235-2531. **Circle No. 703**

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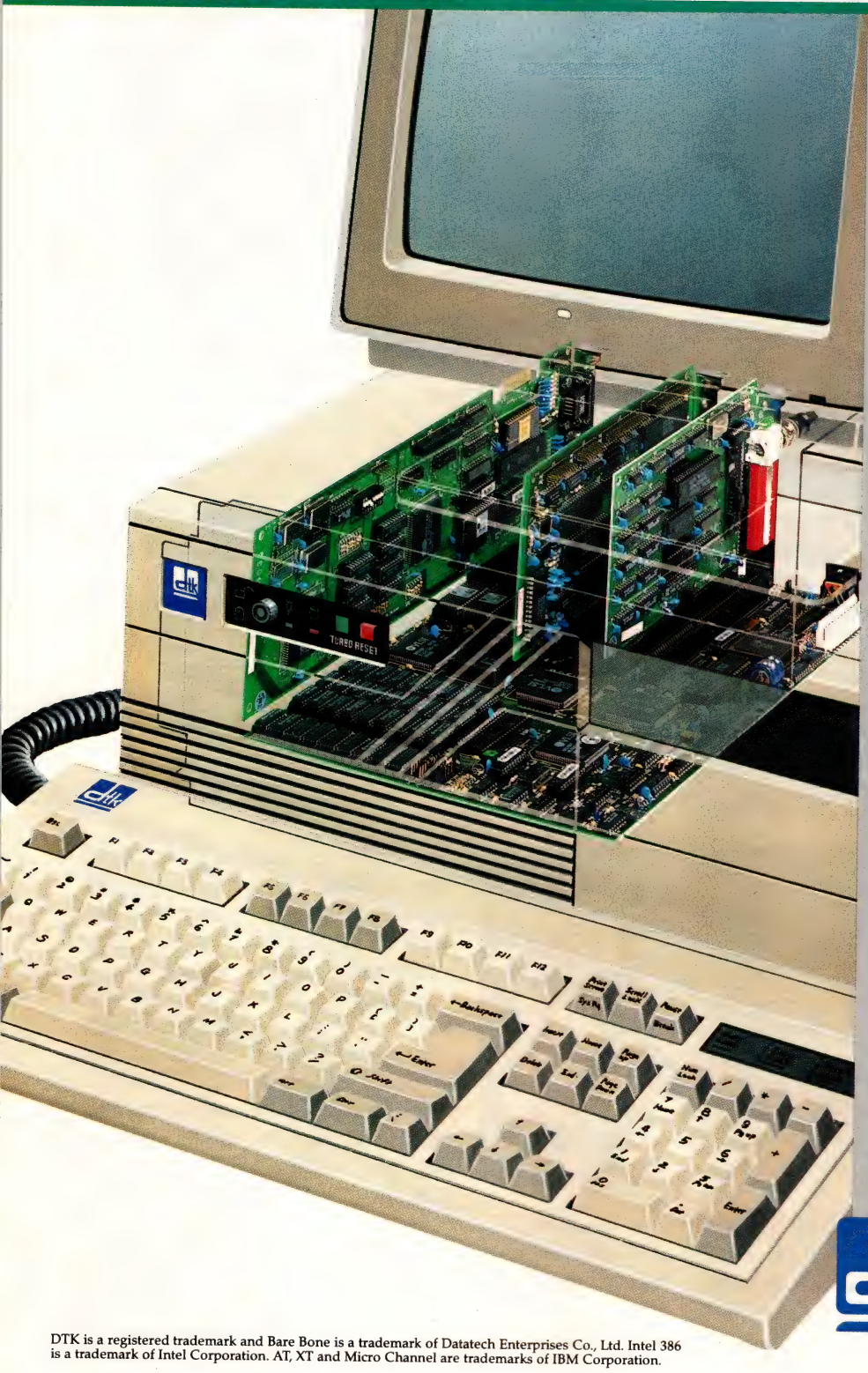

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Input scanner for personal computers has 400-dpi resolution

The Model 400 is the first in the ClearScan Series of input scanners for the IBM PC/AT and Apple Macintosh computers. The handheld model provides 400-dpi, black-and-white resolution when scanning text and graphics artwork. Because it can handle the subtle gray shadings found in black-and-white photographs and color drawings, it provides direct graphics input from books, magazines, and newspapers.

The reading width of the scanner is 4.1 in., and the scan length is as long as 14 in. The device comes with an Industry Standard Architecture (ISA) bus-compatible interface card for IBM PC/AT users. For Macintosh users, the model comes with a power pack and a SCSI box to interface with the computer. The scanner comes with International Microcomputer Software's Presentation Graphics software, which permits the user to scan the input data and then cut, move, rotate, or duplicate the image. The unit also has three contrast settings. A low-contrast setting can eliminate unwanted smudges on a photograph, and a high-contrast setting can provide sharp, black-and-white line art. The scanner costs $295.

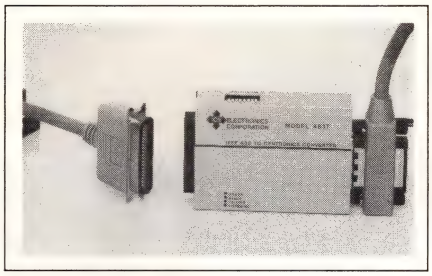
NCL America Computer Products Inc, 1221 Innsbruck Dr, Sunnyvale, CA 94089. Phone (408) 734-1006. **Circle No. 704**

386-based CPU board suits extended STD Bus systems

The ZT 87910 is a 2-board CPU module that serves as a transition product between the 8-bit STD Bus and the company's recently proposed 32-bit extended STD Bus (STD 32 bus). The module automatically senses whether it's plugged into the 8- or 32-bit bus and configures itself for an 8- or 16-bit mode. Therefore, you can develop software and hardware on an existing 8-bit STD Bus and transfer your development work to the STD 32 bus when it's approved in the 1990s.

The board has a 16-MHz 386SX μP and uses Chips and Technologies' (San Jose, CA) IBM PC/AT-compatible chip set. The module will run on the STD 32 bus in the 16-bit mode. Other features include 1M, 2M, or 4M bytes of dynamic RAM; 32k bytes of battery-backed RAM; a 387SX coprocessor socket; a DMA channel; two serial communications ports; a printer port; a keyboard interface; a hard-disk drive controller; three 16-bit counter/timers; three interrupt controllers; and a watchdog timer. The unit costs $2700 and will be available in the first quarter of 1990.

Ziatech Corp, 3433 Roberto Ct, San Luis Obispo, CA 93401. Phone (805) 541-0488. FAX 805-541-5088. **Circle No. 705**



Interface Converter

The 4817 converter attaches an IEEE-488 interface to a Centronics parallel port. The 2.78×3.95×0.86-in., 0.5-lb unit has built-in IEEE-488 and parallel connectors so that it can be placed anywhere between a 488 controller and a Centronics printer port. Velcro straps fasten the converter to any surface. The unit contains a standard 32k-byte print buffer with an option for as much as 130k bytes.

External switches on the 4187 let the user set the IEEE-488 address or the mode of operation. Operational modes include addressed IEEE-488 to Centronics interface, listen-always IEEE-488 interface, Centronics to IEEE-488 talker, and HP printer emulator. The unit draws 500 mA from a 5V wall-mount power supply. From $395; delivery is four to six weeks ARO.

Electronics Corp, 2185 Old Oakland Rd, San Jose, CA 95131. Phone (408) 432-9009. FAX 408-943-1745. TLX 286895.

Circle No. 410

FDDI Controller

The V/FDDI 3211 Falcon is a VMEbus node controller for the Fiber Distributed Data Interface (FDDI), which transfers data over a fiber-optic LAN at 100M bps. The single 6U VMEbus board uses Advanced Micro Devices' Supernet chip set for communications control. The board implements a single attachment station on an FDDI token-passing network, which can have as many as 500 stations separated by 2 km of fiber-optic cable. Two boards can be configured as a dual-attachment station, which provides a degree of fault tolerance. The board has a dual-port 256k-byte buffer that decouples data traffic between the network and the VMEbus. It can operate as a 32-bit master with 32-or 24-bit addressing or as an 8- or 16-bit slave with 16 address bits. $8000.

Interphase Corp, 2925 Merrell Rd, Dallas, TX 75229. Phone (214) 350-9000. FAX 214-352-4124.

Circle No. 411

DSP Board

The VE-32C-01V 4-processor, VMEbus DSP board targets computationally intensive applications. Based on the AT&T DSP32C proc-

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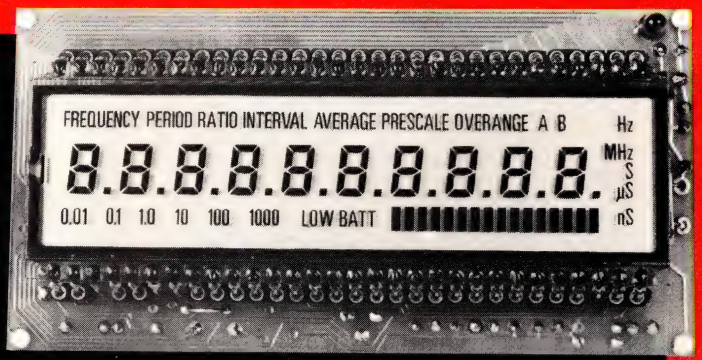
High Performance Universal Counter Timer Module/Panel Meter



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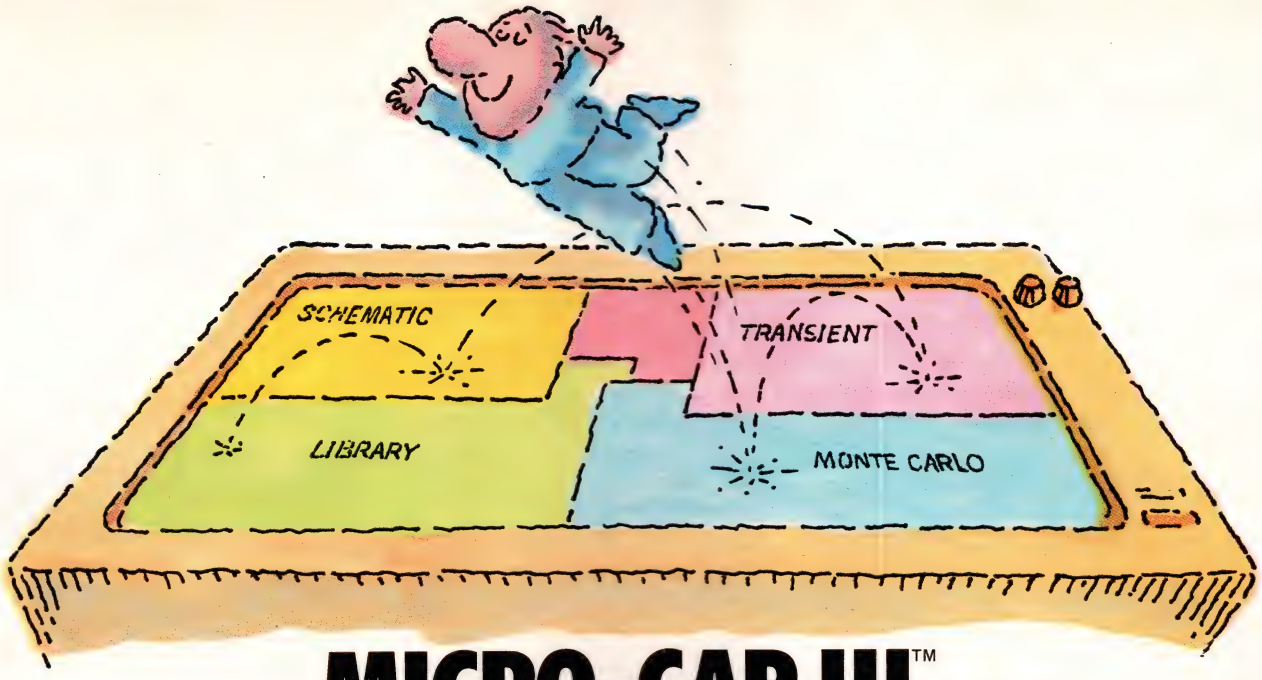

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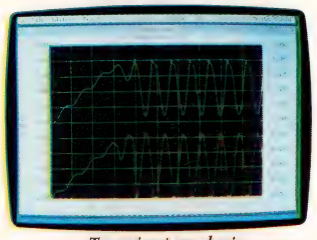
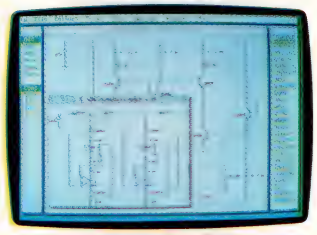
MICRO-CAP III,™ the third generation of the top selling IBM® PC-based interactive CAE tool, adds even more accuracy, speed, and simplicity to circuit design and simulation.

The program's window-based operation and schematic editor make circuit creation a breeze. And super-fast SPICE-like routines mean quick AC, DC, Fourier and transient analysis — right from schematics. You can combine simulations of digital and analog circuits via integrated switch models and macros. And, using stepped component values, rapidly generate multiple plots to fine-tune your circuits.

We've added routines for noise, impedance and conductance — even Monte Carlo routines for statistical analysis of production yield. Plus algebraic formula parsers for plotting almost any desired function.



Transient analysis



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CIRCLE NO 87

essor, the single-slot board executes a 1024-point FFT algorithm in 1 msec. Each of the four processors can multiply two 3×3 matrices in 2.2 μsec. The board achieves peak-performance ratings of 50 MIPS and 100M flops. Aside from its 1536 32-bit words of on-chip RAM, the board supplies 32k to 128k bytes of zero-wait-state static RAM for each of the DSP chips. An on-chip serial port provides a 6.25M-bps communications link between the processors. The VMEbus P2 connector also has access to this daisy-chained link. Separate 16-bit I/O ports operate with transfer rates as fast as 10M words/sec. $7650 (10) with 32k bytes of RAM per processor. Delivery, six to eight weeks ARO.

Valley Enterprises Inc, RD #4, Rt 309, Tamaqua, PA 18252. Phone (717) 668-3737.

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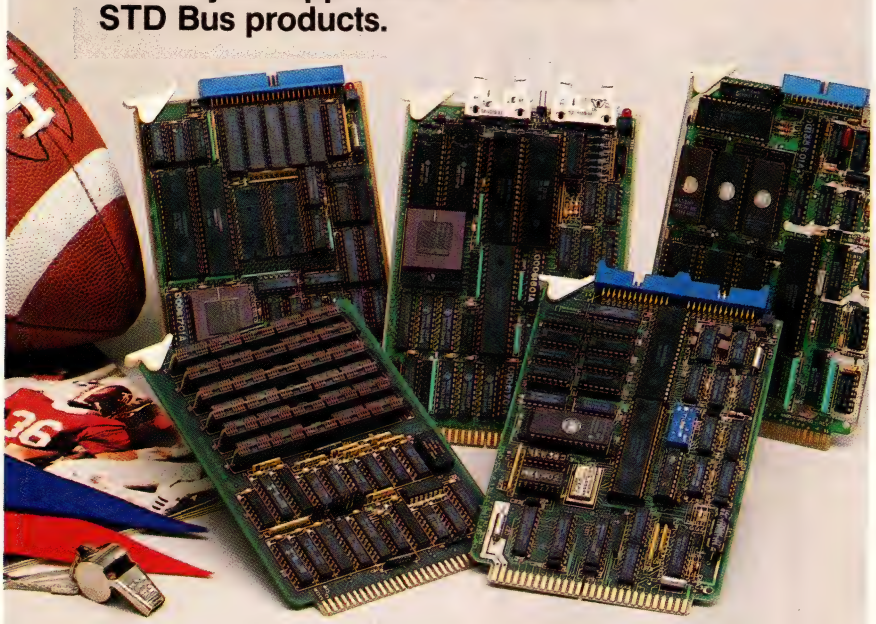

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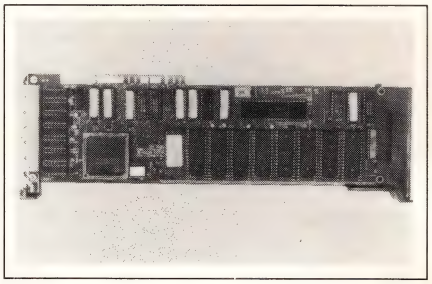

Nine-Channel Communication Card

Targeted for IBM PS/2 computers, the MCSS-91M serial communication board provides nine independent RS-232C serial ports. A 15-MHz 8032 microcontroller handles the data queues, status, and UART interrupts.

The card occupies four I/O addresses, which are selectable using programmable option-select registers. You can access the card directly or through Int 14H of the BIOS for DOS compatibility. Either way, eight of the channels are always interrupt driven for transmit and receive functions with automatic Xon/Xoff handshaking. CTS/DTR (clear-to-send/data-terminal-ready) handshaking is available for six of the channels.

Baud rates range from 110 to 57.6k baud. The base model has a 32k-byte data buffer, which is expandable to 1M byte. Six RJ-11 plugs free up your computer's back panel by allowing all nine channels to come out of one slot. You can install multiple boards and control as many as 130 channels via DOS. $995 for base model with 32k bytes of RAM.

Gtek Inc, Box 2310, Bay St Louis, MS 39521. Phone (800) 255-4835. FAX 601-467-0935.

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THEMIS COMPUTER

80486 Mother Board

The 80486 mother board operates at 25 MHz, and according to the company's benchmark tests, it triples the performance of an 80386 25-MHz mother board. In addition to the on-chip 8k-byte cache and floating-point unit resident on the 80486 μP, the board has an option for a 64k, 128k, or 256k-byte, second-level cache. Onboard memory is expandable from 1M to 16M bytes. In addition, the mother board contains six 16-bit and two 8-bit IBM PC-compatible expansion slots that are hardware selectable to operate at either 8.3 or 12.5 MHz. In addition to its Phoenix BIOS, the board comes with utilities to activate the on-chip cache and second-level cache, to software select the CPU operating speed, and to relocate IBM EGA code and BIOS in system RAM. From $3500.

Micronics Computers Inc, 935 Benecia Ave, Sunnyvale, CA 94086. Phone (800) 234-4386; in CA, (408) 732-0940.

Circle No. 414

STD Bus PC

The CPU-XT single-slot STD Bus module includes all the functions typically found inside an IBM PC/XT computer except disk drives and a power supply. The module, which measures 6.5 × 4.5 × 1 in., can host an Intel 8088 or NEC V20 μP at clock speeds as fast as 9.54 MHz. The card also includes 128k bytes of EPROM and 256k to 640k bytes of RAM. It has a keyboard interface, a timer, a disk controller, a graphics controller, and a battery-backed clock calendar. The disk controller can interface to two floppy- and two Winchester disk drives. The graphics controller is compatible with LCDs and monochrome, IBM CGA, and plasma displays. $995, includes serial and parallel ports.

Computer Dynamics, 107 S Main St, Greer, SC 29650. Phone (803) 877-8700. **Circle No. 415**

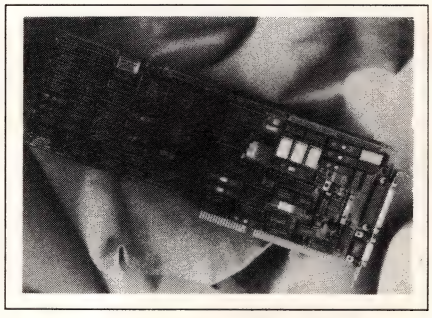
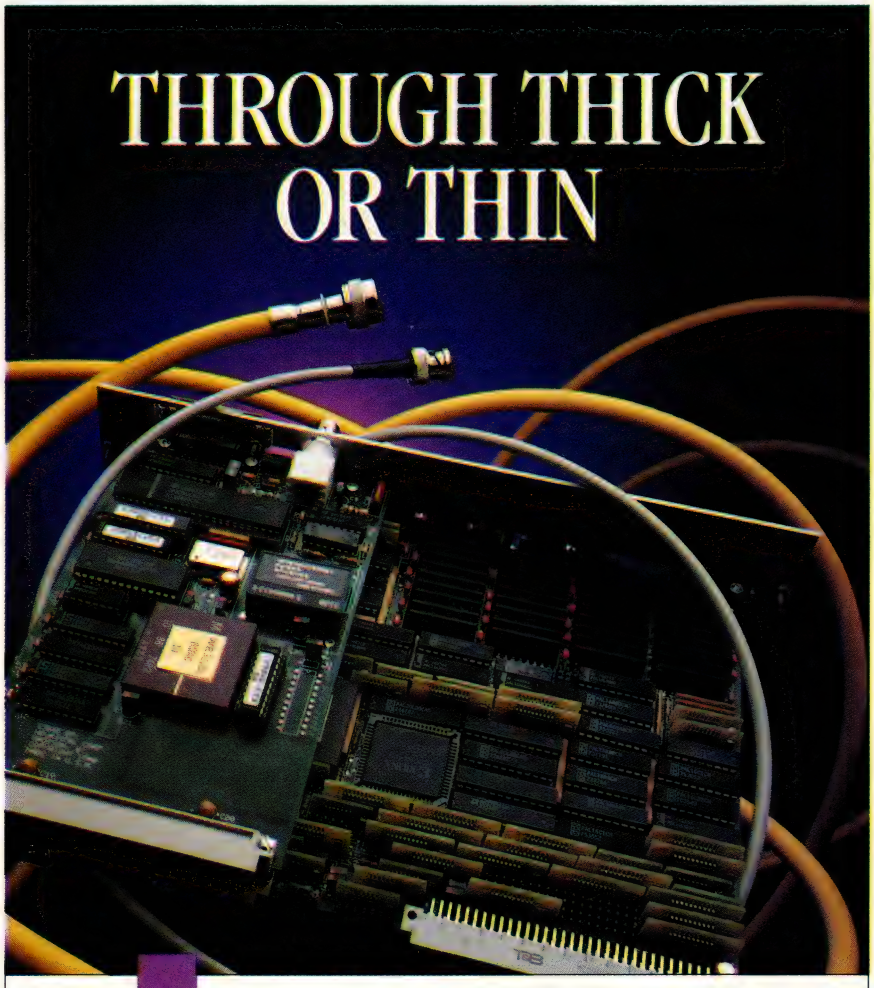


Image-Processing Board

The Oculus-500 is an image-processing board for IBM PC/ATs and compatible computers. It consists of a full-size AT mother board, which



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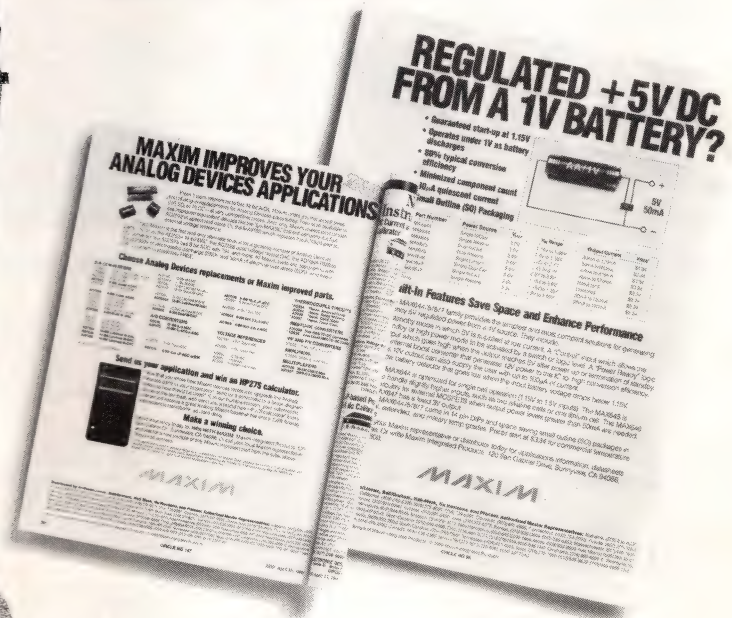

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One of the board's daughter cards expands the 2M-byte frame memory buffer to 4M bytes. The optional Multiple Scan Input Processor card uses another expansion slot to provide either an 8- or 12-bit A/D converter, which can sample video signals conforming to RS-170, RS-330, and CCIR (International Radio Consultative Committee) standards. $6995 to $9995, depending on configuration.

Coreco Inc, 6969 Trans-Canada Hwy, Suite 113, St Laurent Quebec, Canada, H4t 1V8. Phone (514) 333-1301 or (800) 361-4914. FAX 514-333-1388. **Circle No. 416**

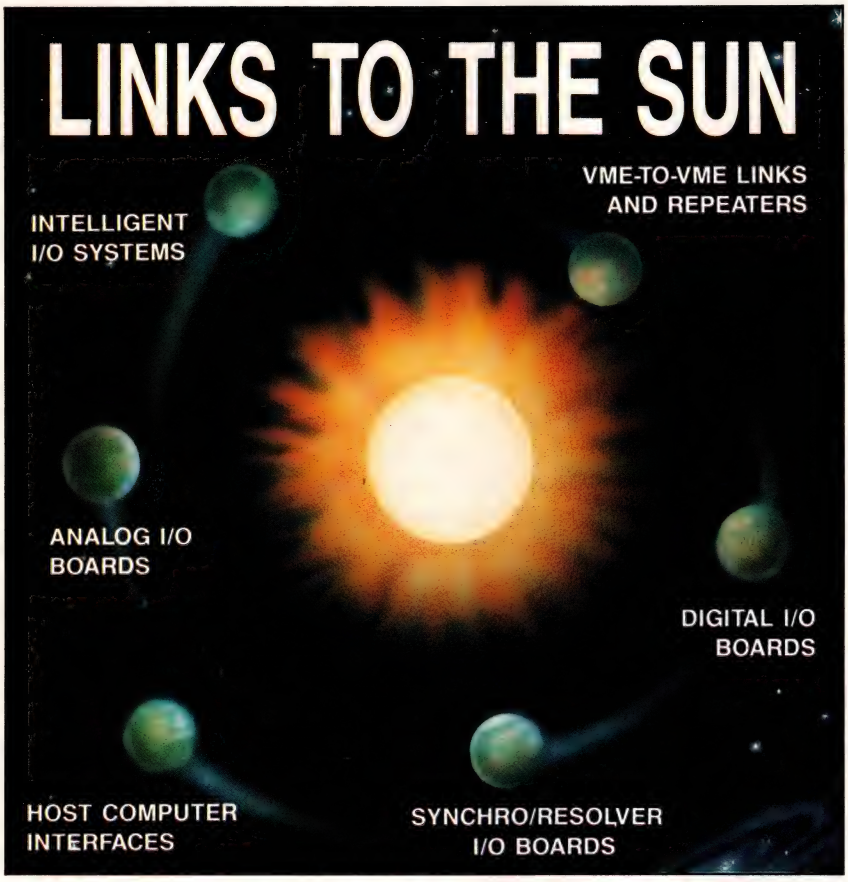
ISA bus DSP Board

The ZPB34 is a DSP plug-in board for IBM PC/AT-compatible computers. The board features a 50-MHz AT&T WE DSP32C, from 64k to 576k bytes of RAM, and two sets of buffered serial I/O ports that provide connections to both internal and external devices. The devices may be other DSP boards for increased processing power or an array of A/D or D/A converters. The DMA controller on the DSP chip can transfer data to and from the serial I/O ports without interrupting data processing. Floating-point calculations occur at 25M flops. Performance figures include 1024-point complex FFT in 3.2 msec, a FIR filter with 80 nsec per tap, and a 32-bit multiply and accumulate in 80 nsec. A Utilities Program lets you download, edit, and execute programs on the board. 64k-byte version, $1995; 576k-byte version, $4995.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (800) 548-6132. **Circle No. 417**

VMEbus CPU Board

The HK80/V960E is a VMEbus CPU board based on Intel's recently announced 960CA RISC CPU. Targeted for real-time embedded applications, the board de-



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CIRCLE NO 17

LINEAR TECHNOLOGY

DESIGN NOTES

Number 29 in a series from Linear Technology Corporation *December, 1989*

A Single Supply RS232 Interface for Bipolar A to D Converters

Sean Gold

Designing circuitry for single supply operation is often an attractive simplification for reducing production costs. Yet many applications call for just a few additional supplies to solve simple interface problems. The example presented here describes how an advanced RS232 interface can simplify an A to D converter which processes bipolar signals.

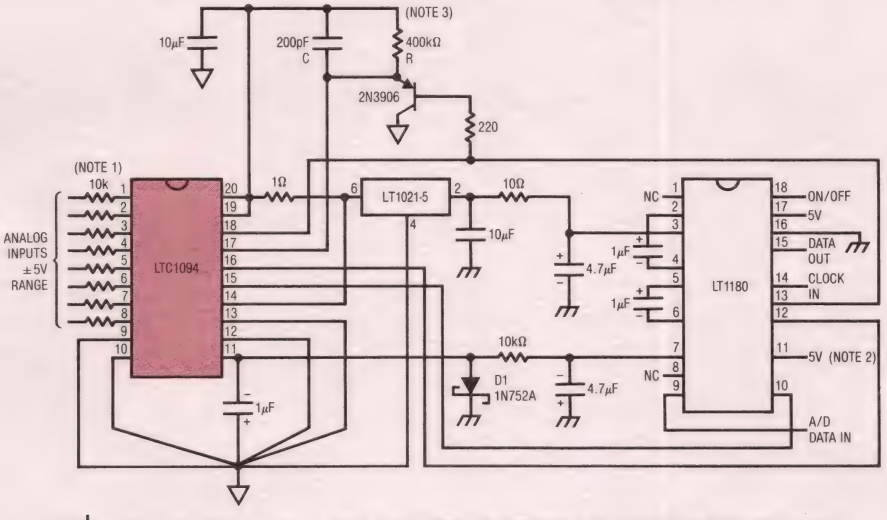
The LT1180 RS232 transceiver includes a charge pump which produces low ripple supplies with sufficient surplus current to drive a CMOS A to D converter and precision voltage reference. The circuit in Figure 1 operates from a single 5V supply, and draws a total quiescent current of only 37mA. These features make the circuit ideal for applications which must process bipolar signals with minimal support electronics.

The LTC1094 serial A to D converter requires both a low noise supply and reference voltage for accurate operation.[1] These design problems are solved with an LT1021 precision reference, which delivers a stable, low noise, 5V signal from the LT1180's V^+ output. Relatively large storage and filter capacitors must be used with the LT1180 to reduce the noise in the system below 1mV for a 12 bit system. Construction also requires close attention to the layout of the system grounds and other aspects of circuit board design to avoid noise problems.[2]

To accommodate bipolar inputs ($-5 < V_{IN} < 5$), the LTC1094's negative rail must be biased beyond the extreme signal swing, but below absolute maximum ratings for the supplies. A 5.6V Zener diode, D1, provides a sufficient bias because the V^- pin draws very little current.

The A to D converter communicates with a remote controller via three wires, which carry the clock, the configuration word, and the output data. The chip select signal, $\overline{CS}$, is generated from the incoming clock with a peak detector, constructed with a single PNP transistor. R and C are designed to hold the $\overline{CS}$ pin low for at least one clock period. Assuming the logic

Note 1: Refer to the data sheets for the LTC1094/LTC1294.
Note 2: An excellent reference on the subject of grounding and low noise circuit design is: "An IC Amplifier User's Guide to Decoupling, Grounding, and Making Things Go Right for A Change," by Paul Brokaw, Analog Devices Application Note.



NOTE 1: 10kΩ CURRENT LIMIT RESISTORS CAN BE REMOVED IF THE INPUTS ARE GUARANTEED NOT TO EXCEED THE LT1094's SUPPLY VOLTAGES.
NOTE 2: DRIVER OUTPUTS CAN BE PARALLEL FOR GREATER CURRENT DRIVE.
NOTE 3: SELECT $RC = 4T_{CLOCK}$, MINIMIZE C.

Figure 1. A/D Converter Interface

threshold in the LTC1094 is 1.4V, two useful rules of thumb for selecting R and C are: Design RC to be at least four times the clock period. And select C as small as possible to start the converter quickly. Minor aberrations in the $\overline{CS}$ signal are unimportant because the $\overline{CS}$ pin is level sensitive. The PNP is biased from the clean reference supply so very little noise is coupled into the A to D. Additional buffers are unnecessary because the peak detector drives a CMOS input.

The operating sequence for the LTC1094 is shown in Figure 2. The $\overline{CS}$ signal switches to a low state less than 1μs after receiving the system clock, and the configuration word may be transmitted after one clock cycle. After the 18 clock cycles required to complete the conversion, the clock must shut off to allow $\overline{CS}$ to switch to a high state for at least 2μs — the minimum time between conversions. The operating sequence may then be repeated.

A single conversion cycle is shown in Figure 3. The LT1180's maximum data rate limits the clock speed to 100k baud. The input voltage is 3.33V which generates a bit pattern of alternating 1's and 0's. Trace B shows the Chip Select signal, and Trace C shows the gating pulse for the system clock. The complete conversion cycle for a 12-bit converter using an LTC1294 is listed in Figure 4. For this example, the gating signals are adjusted to allow for the two extra bits of data.[3]

Note 3: The LTC1094 in Figure 1 was directly replaced with an LTC1294, with no changes to the circuit.

MSB First Data (MSBF = 1)

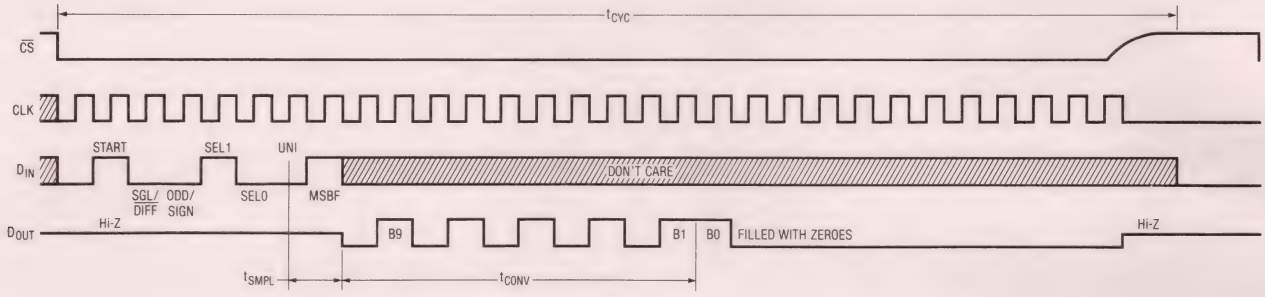


Figure 2. LTC1093/4 Operating Sequence Example: Differential Inputs (CH4 +, CH5 –), Bipolar Mode

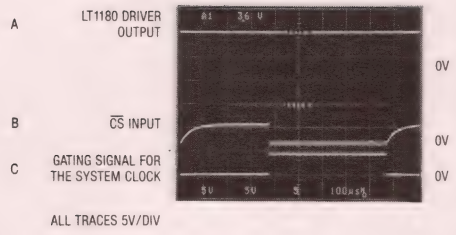


Figure 3. 10 Bit Converter Interface

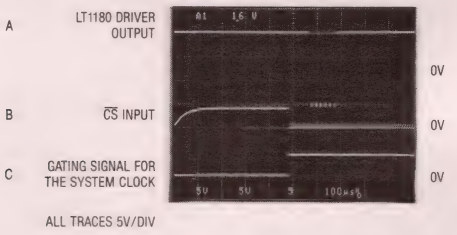


Figure 4. 12 Bit Converter Interface

For literature on RS232 products, call **(800) 637-5545.**
For applications help, call (408) 432-1900, Ext. 456.

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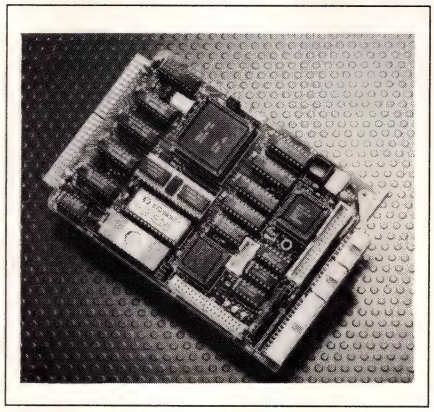
Heurikon Corp, 3201 Latham Dr, Madison, WI 53713. Phone (800) 356-9602. FAX 608-831-4249. **Circle No. 418**

EL Display

The FP-XT is a complete IBM PC/XT computer that's fully integrated onto an electroluminescent display. Unlike CRTs, electroluminescent flat panels are immune to EMI radiation and the disturbing effects of magnetic fields. The system uses NEC's 8-MHz, CMOS V40 μP. It comes with a ROM-based BIOS, 640k bytes of RAM, 128k bytes of ROM, a real-time clock, two serial ports, one parallel port, and a keyboard port. A 1- or 2-card slot passive backplane is an expansion option. The standard model comes with a monochrome electroluminescent display that provides 640×350-pixel resolution. An optional gray-scale model provides 16 levels of gray-scale IBM EGA resolution and is compatible with programs written for multicolor CRTs. The total package depth is 2.39 in., including a touch-switch input system. Standard units from $1995; gray-scale models from $2495. Delivery, six to eight weeks ARO.

Emerald Computers Inc, Industrial Products Group, 7324 SW Durham Rd, Portland, OR 97224. Phone (503) 620-6094. FAX 503-639-7932. **Circle No. 419**



STD-Bus CPU Card

The 9500A CPU card for the STD Bus includes a floppy-disk controller that interfaces with two standard 3½- or 5¼-in. floppy-disk drives. The card also has two programmable RS-232C ports and 24 TTL-compatible digital I/O lines for driving Opto-22 racks. In addition, an 8-MHz V25 μP and 128k bytes of RAM (expandable to 512k bytes) come with the card. A minimum of 620k bytes of STD Bus memory is addressable for a total address range of 1M byte.

The card has a matrix-type keyboard port, an alphanumeric-type output display port, and a 16-bit timer output. It comes with STD Basic III, which is a multitasking compiler in a 64k-byte ROM. The compiler uses the same syntax as Basic, but it includes extensions to manipulate bits, process interrupts, and acquire data on the STD Bus. $545.

Octagon Systems Corp, 6510 W 91st Ave, Westminster, CO 80030. Phone (303) 426-8540. FAX 303-426-8126. **Circle No. 420**

5¼-In. Disk Drives

The 5¼-in. Elite disk drives have storage capacities of 1.2G and 1.5G bytes, which they attain using the Zonal Bit Recording method. The drives have an average access time of 12 msec because their rotation speed is 5400 rpm vs the standard 3600 rpm. The increase in spin rate reduces latency time from 8.3 to 5.5 msec; the track-to-track seek time is less than 3 msec.

Other features of the drives include a 3M byte/sec data-transfer rate; SMD-O/E, IPI-2, or SCSI-2 compatible interfaces; vertical or horizontal mounting; thin-film heads; and a 100,000-hour MTBF. The drives utilize 10 disks and have 17 data surfaces with track densities of 1867 tracks/in. The SMD and IPI models have recording densities of 33,660 bpi; the SCSI model is variable between 33,000 and 45,000 bpi. A 1.2G-byte drive starts at $3995.

Imprimis Technology Inc, 12501 Whitewater Dr, Minnetonka, MN 55343. Phone (612) 936-6271. **Circle No. 421**

CPU Board

The Eurocom-6, a CPU board for the VMEbus, uses a 20-MHz 68030 μP and has a 68882 coprocessor. A burst-mode access reads complete 4×32-bit cache lines in 280 nsec from its local 8M-byte dynamic RAM. Gate arrays implement VMEbus interface features such as slot one function, master/slave access, interrupt handler and requester, bus arbiter and requester, block mode, and DMA transfer mode. All these features are software programmable. The board also has 256-byte-wide registers that can serve as semaphores to trigger local interrupt requests in multiprocessor applications. Other features include a SCSI interface with a 64k-byte FIFO buffer, four RS-232C ports, a 16-bit parallel

Text continued on pg 148

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EXTENDED MEMORY	8XC652 (8K ROM)
	8XC552 (8K ROM)
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*Reduced Instruction Set Computer: "Design environments shown above include Data General AViiON workstation, Tektronix DAS 9200 logic analyzer and target board with Macintosh II for software development. ***Software Vendors: Absoft, Aitech, Applied Logic Systems, Diab, Franz, Green Hills/Oasys, Language Processors, Inc., MBP Software, Micro Focus, NKR Research, Silicon Valley Software, Tadpole Technology, Telesoft, Translation Systems, Unisoft, Wollongong, Languages: ADA, BASIC, C++, C, COBOL, FORTRAN, LISP, Pascal, PL/M, Prolog, RPG-II,

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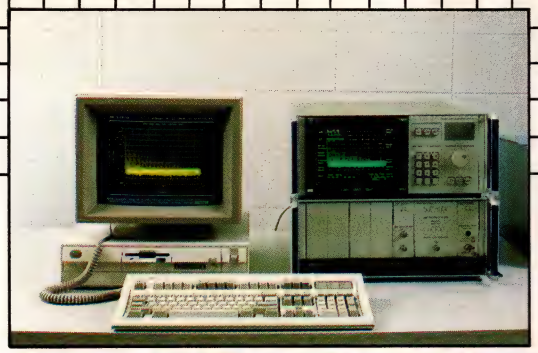

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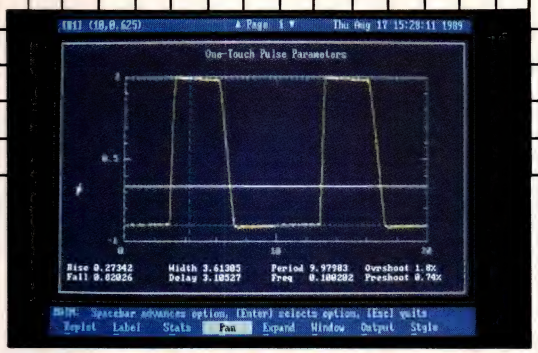
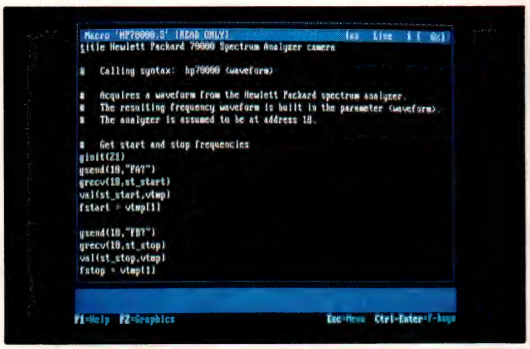


Data Analysis



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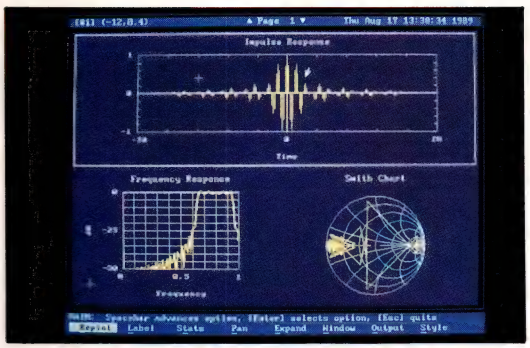

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Simulators for high-speed board design spot trouble

If you design digital boards with clock speeds greater than 25 MHz, you should consider software that performs transmission-line and crosstalk analysis of your circuit design.

Margery Conner,
Regional Editor

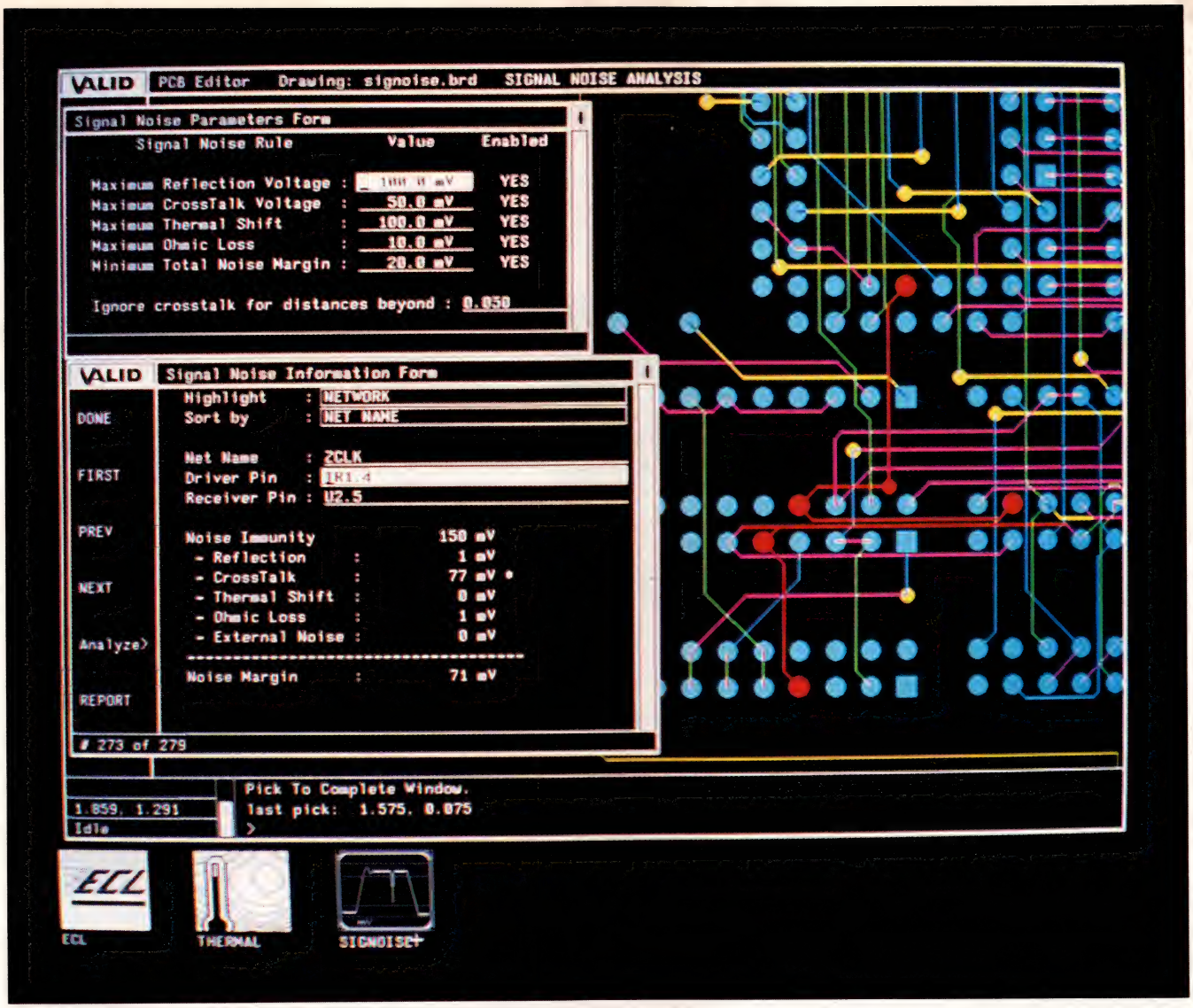
At high speeds, a pc-board trace behaves like a transmission line, with all the attendant ill effects. Transmission lines generate reflections and ringing, and they are susceptible to crosstalk. Although you can usually disregard these noise sources at low speeds, at high speeds they can cause loss of data and mistriggering. Today's transmission-line- and crosstalk-analysis packages for digital design can help you pinpoint problem traces and select methods to eliminate these ill effects. (For more information on transmission-line theory in digital design, see pg 131 of the June 23, 1988, issue of EDN.)

The packages fall into two broad categories: screening tools and analysis tools. Screening packages, available from Daisix and Valid, are integral to the companies' pc-board-layout software and give you a relatively quick look at potential problems. Analysis tools, available from third-party developers Quad Design, Quantic, Swiftlogic, and Hyperlynx, perform detailed electromagnetic field simulations. However, before you evaluate the packages' capabilities, you should understand the differences between analysis and screening tools.

Because transmission-line and crosstalk-analysis tools model both linear and nonlinear component characteristics and solve electromagnetic field equations for the transmission lines, they provide you with a more detailed circuit analysis than a purely screening-type tool. The difference lies in the thoroughness of the analyses the tools perform.

Screening-software packages are much less accurate than analysis-software packages because screening software runs faster and performs fewer calculations. Screening packages achieve their speed by using relatively simple load and transmission-line models, and they provide you with a first-cut look at problem areas. Rather than providing actual simulated waveforms at every point in the net, Valid's Signal Noise Analysis (SNA) tool for its Allegro pc-board-layout software, for example, highlights a trace when the noise "budget" is exceeded. Daisix's Boardscope transmission-line simulator does display simulated waveforms; however, it lacks crosstalk-simulation capability.

Screening packages are often run


VALID PCB Editor Drawing: signoise.brd SIGNAL NOISE ANALYSIS
Signal Noise Parameters Form
Signal Noise Rule Value Enabled
Maximum Reflection Voltage : YES
Maximum CrossTalk Voltage : 50.0 mV YES
Maximum Thermal Shift : 100.0 mV YES
Maximum Ohmic Loss : 10.0 mV YES
Minimum Total Noise Margin : 20.0 mV YES
Ignore crosstalk for distances beyond : 0.050
VALID Signal Noise Information Form
DONE
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NEXT
Analyze>
REPORT
Highlight : NETWORK
Sort by : NET NAME
Net Name : ZCLK
Driver Pin : IR1.4
Receiver Pin : U2.5
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- Reflection : 1 mV
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- Thermal Shift : 0 mV
- Ohmic Loss : 1 mV
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A screening tool for pc-board-layout packages, the Signal Noise Analyzer from Valid works with the pc-board-layout software Allegro.

by a user with little understanding of transmission lines. Valid, for example, sees the most common user of SNA as the pc-board-layout designer, not the circuit designer.

How transmission lines and loads are modeled is critical to the accuracy of the simulated reflections for both screening and analysis tools. The screeners assume the response of the load to be linear, while the analysis packages, in general, can simulate both linear and nonlinear loads. Whether you use ECL, fast CMOS, or fast TTL will determine whether you need nonlinear models.

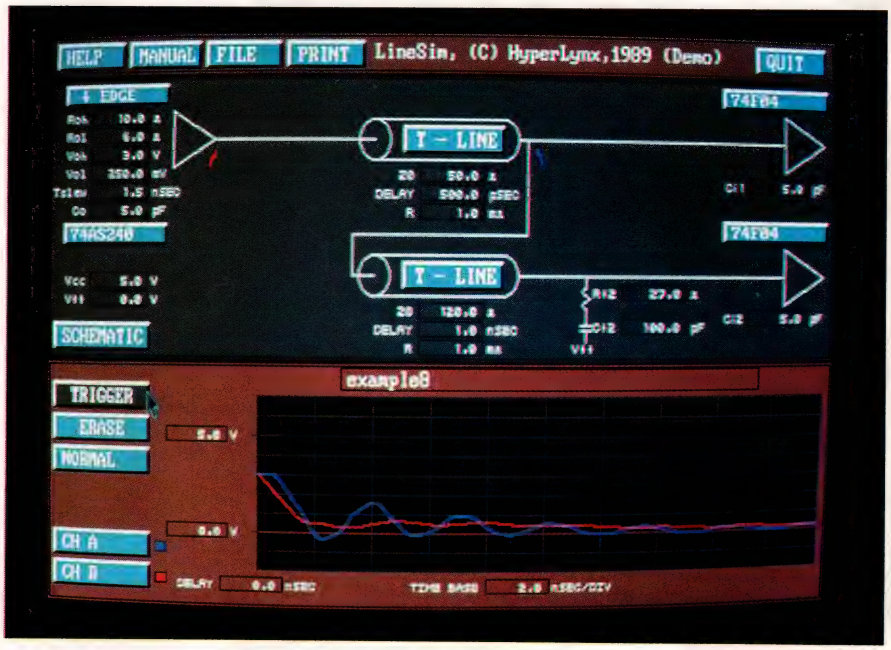
ECL logic is basically linear in its response, so if your design is in ECL, the ability of a package to simulate nonlinearity won't be important. However, high-speed TTL and CMOS are not linear. For example, CMOS devices have a Schottky diode clamp on the input to prevent the input voltage from swinging too low—this negative voltage clipping cannot be accounted for in a linear-only model.

No GaAs support—yet

Note that none of the packages support GaAs logic families, which are often pointed to as the emerging high-speed logic technology. Larry Rubin, president of Quad Design and developer of its Transmission-Line Calculator (TLC) and Crosstalk XTK packages, gained much of his experience in transmission-line analysis while at Vitesse (Camarillo, CA), a GaAs manufacturer. He says that the capability to include GaAs component models in high-speed board-level simulators does exist, but so far there just isn't enough interest from the design community.

Screening packages also make many assumptions about circuit topology. SNA, for example, is tuned for a daisy-chain circuit. But, few real-life circuits are exclusively daisy chained. However, for a quick screen of any digital circuit, the results will be fairly accurate, claims Shiv Tasker, Valid's product marketing manager. Further, Tasker points out, there are so many uncertainties in pc-board manufacturing that being exhaustively accurate in your simulation serves no purpose. For example, traces will vary in their thickness and width, causing the characteristic impedance (Z_0) to vary from the ideal and affect most transmission-line calculations.

For users who want more information, such as waveform display of simulated reflections, Valid has developed an interface between Allegro, SNA, and Quantic Laboratories' Greenfield, an electromagnetic field analyzer and time-domain simulator. The marriage is mutually beneficial in that Allegro gains the ability to let users analyze in detail traces flagged by SNA, and display the simulated transmission-line voltages of the traces that exceed their noise-voltage budget. These features help SNA appeal to more sophisticated users. Greenfield, on the other hand, gains a front-end tool that gives a quick look at an overall laid-out design and flags critical nets; Greenfield by itself has no ability to automatically screen a design for critical nets. **Table 1** lists the pc-board-layout software interfaces supported by the packages discussed in this article.



For a trace-by-trace analysis, or as a refresher on transmission-line fundamentals, Hyperlynx's Linesim is a low-cost tool that runs on a PC/AT.

Modeling method affects speed

The method of writing or modifying a simulator's models affects its speed as well as its accuracy. The analysis packages from Quad De-

Not for transmission-line beginners

All of the packages for high-speed digital boards mentioned in this article make some restrictive assumptions about the transmission lines and component models. Although you can alter the parameters of the transmission line or component models, it's generally either impossible or difficult to change the models themselves. If you need a high level of control over your analysis and you have a good understanding of transmission-line theory, you may benefit from using a microwave CAE package such as Libra from Eesof.

Libra models are all built from Spice descriptions at the transistor level. The software will display the voltage at any point in your design, and you can switch back and forth from the pc-board-layout package to Libra, but the software does not automatically flag voltages that violate design rules. Keep in mind that Libra is used by microwave designers who are trying to control, not minimize, transmission-line effects, so it isn't set up to flag responses that are only considered undesirable in digital design. In addition, all modeling is done at the transistor level, so if you need to model a driver or receiver not in the Libra library, you must modify or create a Spice model.

Screening packages are integral to the companies' pc-board-layout software, and they give you a relatively quick look at potential problems.

sign, Quantic, and Swiftlogic differ in the way they model the component loads. Quad Design uses a behavioral model in its packages that contains no information about the device's internal circuitry. Rather, it describes the device's load stimulus and response characteristics with voltage and current specifications. For example, a behavioral model specifies the rise time on the voltage and the drive-current capability. Swiftlogic uses a similar approach for its Swiftline transmission-line models, specifying the inflection point for voltage and current curves. Note that these two approaches allow you to build models from device spec sheets, without having any knowledge of the device's internal design.

Greenfield doesn't include a library of models. Again, it relies on Valid's SNA software for the initial screening of the entire circuit; it doesn't need to have models for all devices in the design. Once Valid has flagged critical nets, Greenfield calculates Z_0 for the traces and performs the simulation of the signals using generic drivers and loads. However, SNA's screening is for linear-device responses only, so the screening step will not be able to account for nonlinear-device characteristics.

The disadvantage to Quantic's approach is that you are not using the actual device characteristics to perform the evaluation. Although Greenfield supports an interface to Spice for component modeling, Rubin claims that Spice models are time-consuming to develop and that they require intimate knowledge of a device's internal circuitry. Julius Poltz, Quantic's vice president of R&D, counters that the generic models are more than adequate for running transmission-line calculations. Further, for simulations too critical for generic models, you need the accuracy of a Spice model, not a behavioral model. (For more information on software for Spice-based analog modeling of transmission lines, see **box**, "Not for transmission-line beginners.")

Because analysis tools perform more complex calculations, their runtime is longer than that of screening tools, which perform more cursory evaluations. In addition, one analysis package's runtime may be longer than another's. For example, because TLC doesn't do a modal analysis and is less computationally intensive, it may run faster than Greenfield. The difference in accuracy will not be great and will only show up in the rate of decay of the reflected signal.

Table 1 — Transmission-line and crosstalk-analysis CAE tools for digital pc boards

Manufacturer/Product	Transmission-line modeling	Crosstalk-noise modeling	Linear-load models	Nonlinear-load models	Trace types: Strip	Microstrip	Buried strip	Dual strip	Simulated waveform display	Margins only	Screening tool	Analysis tool	Workstation support	PC-board-layout-software interface	Base price
Daisix															
Boardscope	✓								✓		✓	✓	Sun 3 & 4, SPARCstation, Sun 386i	Daisix PCB, CAD	$25,000
Hyperlynx															
Linesim	✓		✓	✓	✓	✓			✓			✓	PC/AT	—	$595
Quad Design Technology Inc															
Transmission Line Calculator	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	Sun 3 & 4, SPARCstation, Apollo 3000 & 4000, MIPS 2000, Data General AViiON, VAXstation, DECstation, HP 9000	Mentor, Valid, Callay, PCad, SciCard	$10,000
Crosstalk XTK (XFX & XNS)		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			$25,000
Quantic Laboratories Inc															
Greenfield	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	Sun 3 & 4, Apollo 3000 & 4000, HP9000	Valid, Intergraph	$35,000
Swiftlogic Ltd															
Swiftline	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Apollo 3000 & 4000	Mentor	$12,500
Swiftnoise		✓	✓		✓	✓	✓	✓			✓				$12,000 ($17,500 for both)
Valid Logic Systems															
Signal Noise Analysis	✓	✓	✓		✓	✓	✓	✓		✓	✓		Sun 3 & 4, VAXstation, DECstation	Valid Allegro	$7,000

Analysis tools available from third-party software developers perform detailed electromagnetic field simulations.

However, depending on the level of accuracy you need, the difference may be important. The only way you can evaluate the tradeoffs in accuracy for speed is to run sample benchmarks of your own that are tailored for the type of circuit you'll be designing. (For examples of how some companies go about selecting transmission-line and crosstalk-analysis tools, see **box**, "Well worth the extra effort.")

Just as there's a wide variation in how the packages simulate transmission-line effects, there's a similar diversity in crosstalk-simulation techniques. Valid's SNA and Swiftlogic's Swiftnoise only check for noise margins, and use only linear models. Swiftnoise evaluates for crosstalk using De Falco's theorem, which states that you can find the crosstalk voltage at any point by summing the contributions of crosstalk from all other coupled lines. It sums these contributions intelligently; that is, it allows for dielectrical changes and the placement of traces. The easiest trace to characterize is one completely embedded in an inner layer with an adjacent ground plane. Surface traces have a nonuniform dielectric, so the software calculates an effective dielectric constant. Swiftnoise can account for crosstalk from any number of lines; SNA is limited to just two lines.

Crosstalk and transmission-line effects show up on analysis tools, such as Quantic's Greenfield package.

Quad Design and Quantic simulate the exciting signal and the coupled signal appearing on the passive line for both linear and nonlinear signals. This approach requires a modal analysis, which is computationally more intensive, but more accurate, than a summation approach. A modal-analysis approach treats the signals as electromagnetic waves coupling between adjacent traces. For two traces, the software performs a two-mode analysis, characterizing the electromagnetic fields with the associated eigenvalues for three traces, three modes, and so on.

Well worth the extra effort

Transmission-line and crosstalk simulators are new CAE tools, and performing an evaluation of these diverse products is no simple task. Luther Abel, corporate CAD director for Data General (Westboro, MA), says that it took six man-months of evaluating the packages to reach a decision. He notes that rather than working from product spec sheets to make a decision, the engineers brought the packages in-house to evaluate them prior to making their final decision. Also, the Data General engineers performing the evaluation were not novices in transmission-line analysis. They compared the simulator results, not to measured hardware signals, but to transmission lines they modeled previously in Spice.

Bill Potwara at Honeywell (Scottsdale, AZ) also wanted hands-on experience before committing to a crosstalk-analysis package. He had a sample pc board constructed that embodied signal paths he expected to encounter, and compared the simulator results to actual signals.

The lesson to be learned from these companies is that the knowledge, experience, and effort you'll gain from a thorough, hands-on evaluation is well worth the effort.

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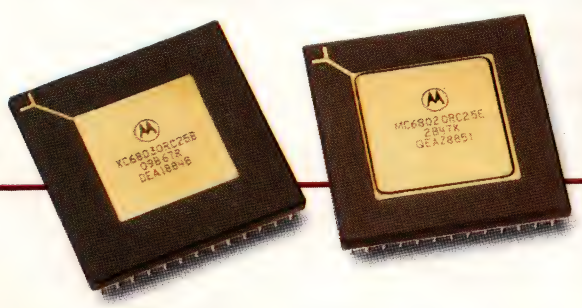

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CIRCLE NO 97

The type of circuits you are modeling will determine whether you need nonlinear models.

It's not necessary to understand eigenvalues and modal analysis to use a modal analysis of crosstalk, but you should consider the relative thoroughness of a modal-analysis approach versus a summation-of-noise-voltage approach. If you just want to take a quick look at noise margins for a board design to determine if you're within set limits, the linear approach is fine. But if you're skating close to the noise limits and need to know the nature of the crosstalk voltage, you may be better off with a modal analysis, because modal-analysis-based packages can display waveforms, rather than just predict when margins will be exceeded.

Brush up on your theory

The majority of today's digital designers are inexperienced in transmission-line analysis. If you fall into this category and are considering a high-speed design, or expect to face such a design in the near future, consider a low-cost ($595) transmission-line-analysis package from Hyperlynx. The package is more than a learning tool: It analyzes your design on a trace-by-trace basis and can flag any limit violations. It doesn't, however, have built-in hooks to existing pc-board-layout packages to facilitate what-if analysis. Nor can it look at a board on a global basis; its analysis is all on individual traces. However, the package is an inexpensive way to analyze your design and refresh your knowledge of transmission-line analysis.

Finally, you should consider some of the nontechnical aspects of a transmission-line-analysis package. Unlike most CAE packages, which are stand-alone and affect only the design engineer, transmission-line packages are usually used in a loop that includes the pc-board-layout designer. Third-party analysis packages assume that the engineer has full access to the design database, which may not be the case. Your company may isolate the design engineer from the pc-board-layout process.

Chances are, when the pc-board design team is evaluating an autorouter, it is not going to put transmission-line-analysis capability at the top of its must-have list. Yet, as high-speed board designs become routine, transmission-line analysis will become a necessary feature that will sway autorouter purchasing decisions. EDN

For more information . . .

For more information on the transmission-line- and crosstalk-analysis tools described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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References

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2. Blood, Wm R, Jr, "MECL System Design Handbook," Motorola Semiconductor Products Inc, 1988.

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High 512 Medium 513 Low 514

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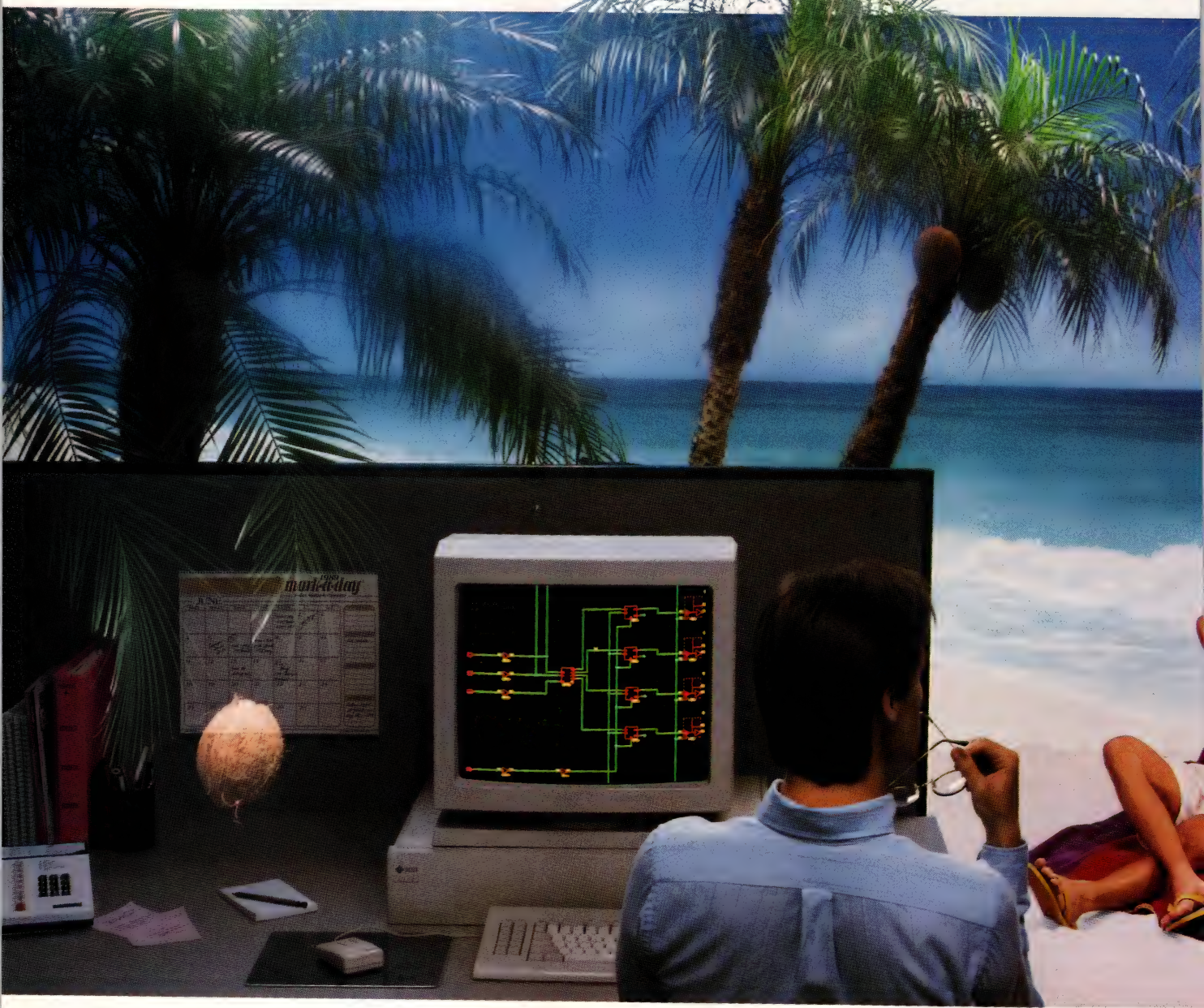

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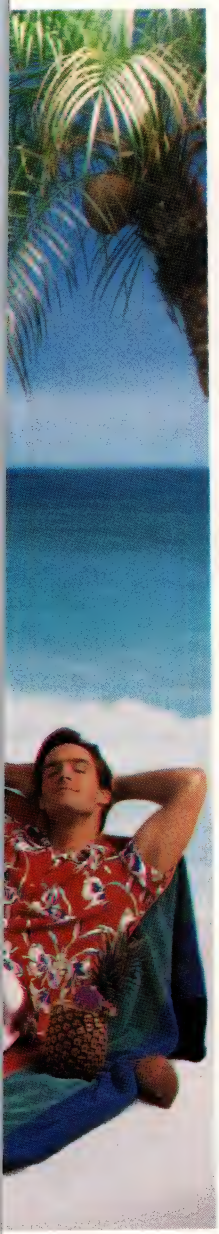

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CIRCLE NO 99

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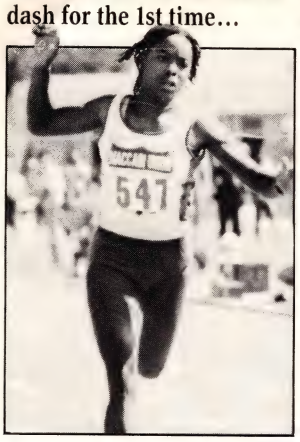
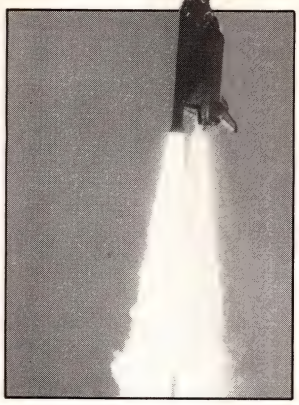


and EDN takes 1st place in readership.

In 1980, the first-ever Chinese Olympic team attends the Winter Games...

and EDN wins 1st place in readership.

In 1981, the Columbia makes the first space shuttle flight...

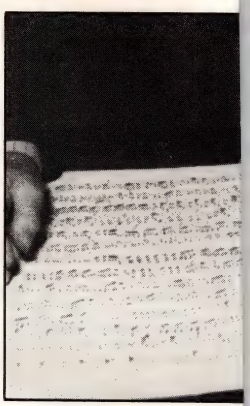


and EDN soars – finishing 1st in readership.

In 1982, Lady Diana, Princess of Wales, has her first child...

and EDN reigns as 1st in readership.

In 1983, the first sympl written by Mozart (at a nine) is discovered...



and EDN is discovered t be 1st in readership.

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	EDN	Electronics
Zenith Electronics	#1	5
Sprague Semiconductor	#1	5
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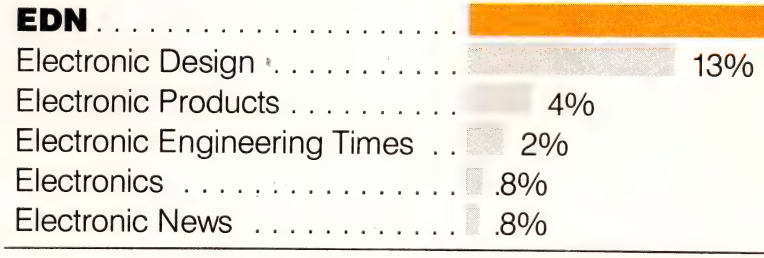
Apex Technology	#1	5
Sipex Corporation	#1	4
Kyocera Northwest, Inc.	#1	NOT INCL.

CUMULATIVE WINS –
% of Readership/Reader Preference Wins* 1978–1989 (to date)



177 studies/256 questions

Percentages add to more than 100% due to ties

*Independent studies are conducted across customer/prospects lists or TIDS lists, not across a magazine's or newspaper's own list, which results in obvious bias. **Results based on the question

'84, Kathryn Sullivan
e first woman to walk
ace...

EDN walks away
a 1st in readership.

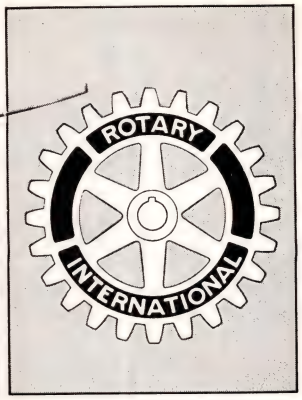
In 1985, Reagan and Gorbachev hold their first summit...

and EDN holds its 1st place in readership.

In 1986, the first non-stop flight around the world without refueling is successful...

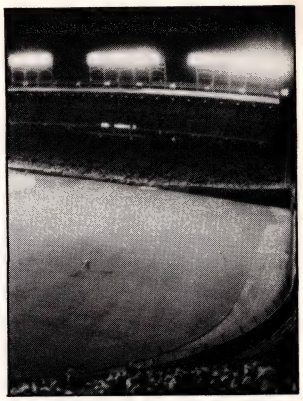
and EDN flies highest as 1st in readership.

In 1987, the Rotary Club admits women for the first time...



and EDN is elected 1st in readership.

In 1988, Wrigley Field in Chicago lights up for the first time...



and EDN shines as 1st in readership.

STS

One Electronics Publication Knows What It's Like Leadership In Readership Reign Continues.

eadership/reader preference study wins:*

Electronic Design	Electronic Products	EE Times	Electronic News
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2	4	3	NOT INCL.
4	3	2	NOT INCL.
2	4	3	6
2	3	4	NOT INCL.
2	NOT INCL.	3	NOT INCL.
3	2	4	5

84%

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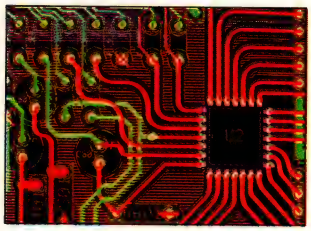

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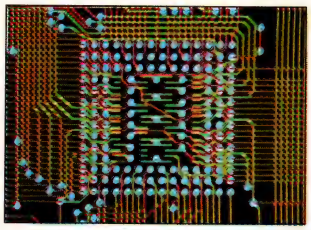

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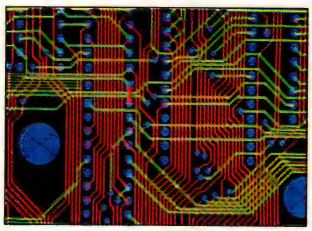

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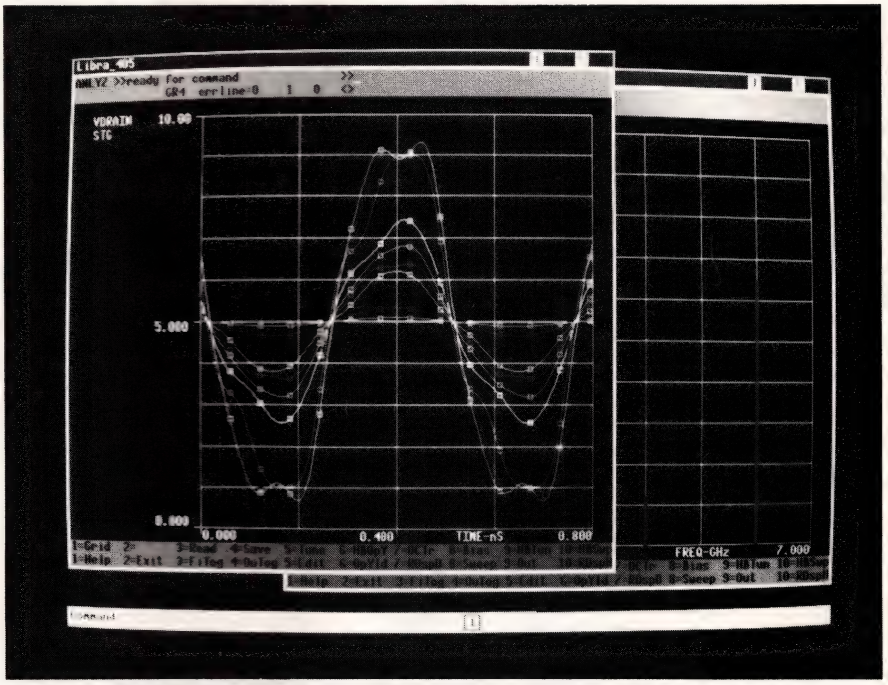
Harmonic-balance simulator optimizes microwave circuits for yield

Version 2.1 of Libra, a harmonic-balance simulator for microwave circuits, has been enhanced by features that increase simulation speed and provide design centering for maximum yield. New algorithms make the analysis of amplifiers and signal-distribution circuits five times faster than previous versions and make mixer analysis 10 or more times faster.

In addition, you can now optimize nonlinear circuit parameters, such as mixer conversion loss and amplifier saturated gain, while taking into account the statistical distributions and manufacturing bounds of circuit elements. Recentering the nominal values of the adjustable elements can improve the manufacturing yield by as much as 25%.

The simulator runs on IBM PCs and compatibles, Apollo DN3000 and DN4000 workstations, Sun 3 and Sun 4 workstations, and the VAX 3100 workstation, as well as Hewlett-Packard series 300 computers. Prices vary from $23,500 to $34,200, depending on the host computer.



EEsof Inc, 5795 Lindero Canyon Rd, Westlake Village, CA 91362. Phone (818) 991-7530. FAX 818-991-7109. **Circle No. 719**

Software package lets you model Darlington and other complex devices

EXModeler is an optional modeling package that works with the vendor's Suxes device-modeling and parameter-extraction package. This option extends the characterization range of the Suxes 20 modeler from simple diode, MOSFET, and bipolar devices to include LDD (light-drain-diffusion), power-FET, and Darlington devices, which the common Spice models cannot handle.

The option gives you macromodeling facilities that are usually found only in simulators. The option also expands the domains of device modeling to include ac and transient characteristics, which are essential for the complete characterization of bipolar devices. These capabilities let you extract multiple transient domain parameters from a single transient measurement. You can define environmental effects such as temperature and radiation to accurately predict device behavior.

The Plus option adds instrumentation drivers to Suxes 20. The drivers can account for the limitations of individual instruments, and let you measure data from MOSFETs, JFETs, GaAs and bipolar devices, diodes, and capacitors.

The package runs on Sun, Apollo, and DEC workstations, as well as on Hewlett-Packard and Cray computers. Suxes 20 costs $25,000, EXModeler costs $10,000, and the Plus option is $2000. All three programs bundled as the Device Characterization Package sell for $35,000.

Electrical Engineering Software Inc, 4675 Stevens Creek Blvd, Suite 200, Santa Clara, CA 95051. Phone (408) 296-8151. FAX 408-296-7563. **Circle No. 720**

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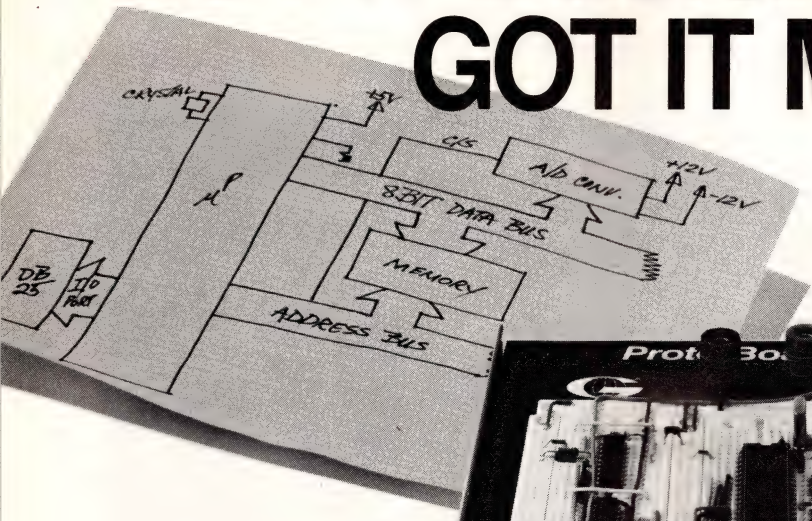

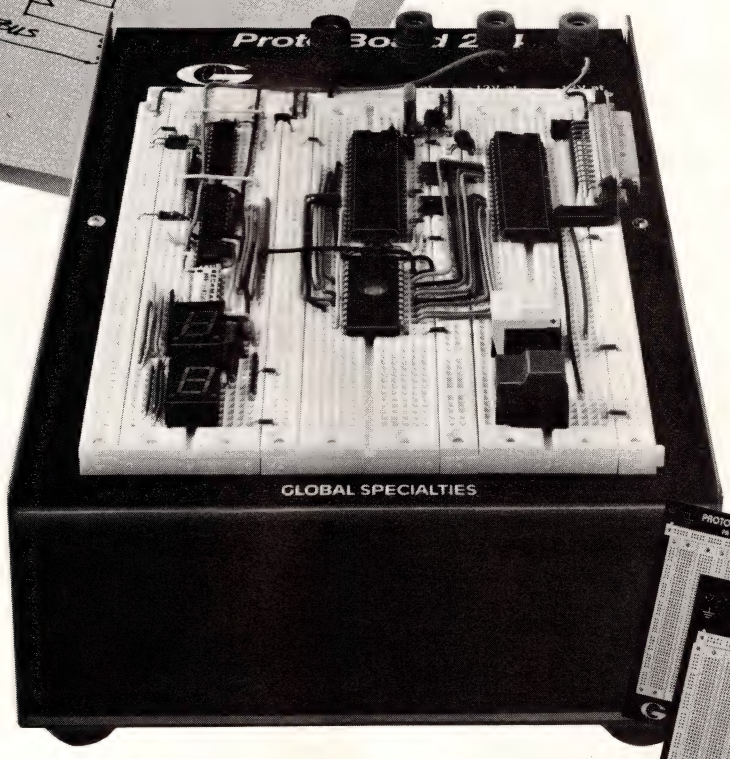

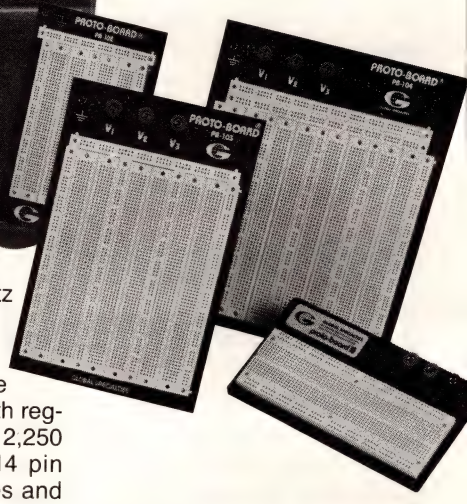

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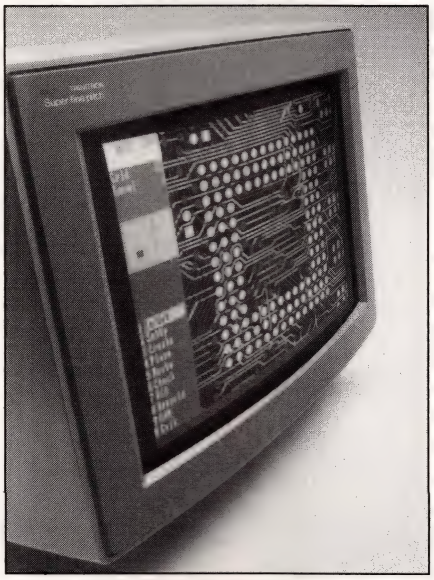
A0010

CIRCLE NO 108

ASIC-design package tracks glitches as they propagate through your system

NavNet is an ASIC-design package that runs on IBM PCs and compatibles under MS-Windows or on Sun workstations under the Sunview multiwindow, multitasking operating system.

The program graphically displays pulse-width violations of your design rules as a waveform. When you select a particular glitch for tracing, the program simultaneously displays the location of the error on the schematic. The hierarchical navigator lets you follow the effects of the error through the schematic, so that you can trace and correct errors in individual functional blocks before resimulation. To maintain connectivity over a multipage schematic, the program automatically highlights connections between functional blocks and alerts you if any wires are left unconnected.



NavNet is tightly integrated with other tools in the vendor's S-MOS Design System, which can also work with tools from OrCAD, Valid, ViewLogic, and Futurenet. The MS-Windows version is available now; prices for a site license start at $2000. The Sunview version will be available in mid-1990.

S-MOS Systems, 2460 N First St, San Jose, CA 95131. Phone (408) 922-0200. **Circle No. 721**

Development kit lets you define, simulate, and document your design in VHDL

Valid Logic Systems' VHDL (VHSIC hardware description language) Development Kit lets you define, simulate, and document your designs with the aid of a VHDL implementation that conforms to the IEEE-1076 standard. The kit comprises a language analyzer, an interactive simulator, a design-database manager, and a schematic interface that allows the automatic generation of VHDL descriptions from schematics in Valid's parts library, which contains more than 4000 components. The kit can perform mixed-mode simulations containing both gate-level and behavioral descriptions, thereby letting you meet the DoD documentation requirements.

To ease the use of the kit with schematics created by tools from other vendors, you can obtain the optional EDIF Schematic Reader. Unlike simple EDIF net list translators, the reader provides you with a complete schematic that you can edit or merge into a larger design. Thus, you can convert ASIC symbol libraries into the Valid format or capture schematics generated by logic-synthesis tools. The reader includes error-checking procedures to maintain data integrity during the translation of EDIF files and to ensure correct logical interpretation of the data, regardless of the source. The program interprets vendor-specific graphic treatments, such as the representation of solder dots or component shapes, in accordance with the EDIF 2 0 0 specification.

The VHDL Development Kit, which runs on DEC and Sun workstations, includes the language analyzer, interactive simulator, design-database manager, and schematic interface. The price is $30,000, and delivery is 90 days ARO. The price of the EDIF Schematic Reader is $7500, with immediate delivery.

Valid Logic Systems, 2820 Orchard Pkwy, San Jose, CA 95134. Phone (408) 432-9400. FAX 408-432-9430. **Circle No. 722**

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It takes time to get the new Nicolet System 500 up and running.

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Nicolet Test Instruments Division

5225-2 Verona Road, Madison, WI 53711, 608/273-5008 or 800/356-3090

CIRCLE NO 109

Nicolet

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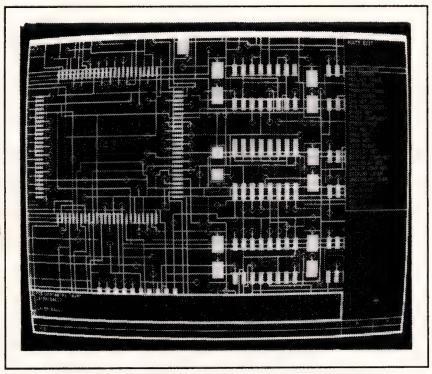

Layout System For PC Boards

Omnicards is an interactive, automatic layout system for pc boards and hybrid circuits. It can handle through-hole, surface-mount, chip-on-board, and thick-film digital and analog designs and can operate on Sun-3, Sun-4, SPARCstation, and Apollo workstations.

Release 4.1 contains many enhancements, including automatic copper-area creation with auto-clearing and autofill facilities; a 2-D drawing package for creating manufacturing drawings; improved rip-up and retry autorouting; better handling of imported net lists; an improved editor; and the ability to use alphanumeric pin identification on components. An optional IGES (International Graphic Exchange Standard) 3.0 interface program lets you export graphics data to mechanical-design and thermal-analysis programs. $12,000.

Task Technologies Inc, 7635 Main St Fishers, Victor, NY 14564. Phone (716) 924-4180. FAX 716-924-4189. **Circle No. 366**

Low-Cost Design Tool

The CapFast CF640 schematic-capture package runs on any IBM PC/AT, PS/2, or compatible computer that has 640k bytes of main memory. The low-cost design tool uses

an incremental design algorithm in conjunction with an overlay memory-management technique. Thus, it does not require any extended or expanded memory. The program can handle individual schematic pages in sizes A through E and can extract net lists for designs with as many as 50 C-size pages (the equivalent of approximately 10,000 design elements).

The CF640 includes an intelligent packaging program that automati-

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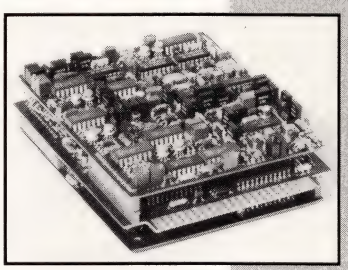
CIRCLE NO 19

A/D Converter

- 1-μsec Throughput •
- Features Integral S/H Amp •



The ADC16M1 16-bit 1-MHz A/D converter plug-in module consists of three pc boards plugged together. It features a design employing a 3-step foldback conversion technique with a transparent partial pipeline to achieve its 1-μsec throughput rate. The high-impedance input circuitry consists of two independent S/H amps operated alternately with a ping-pong switch and a buffer amplifier. Linearity error equals ±0.002% FSR. The unit is available in commercial, industrial, and quasi-MIL grades. Commercial version, $2895. Request quantity prices

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341 E. Camelback, #D
Phoenix, AZ 85012

Phone: (602) 266-2687 Fax: (602) 264-1905

CIRCLE NO 20

cally assigns reference designators and pin numbers to physical packages; provides interfaces to Xilinx tools, Abel tools, and symbol libraries; and has a PADS-PCB back-annotator feature. You can also get interfaces to Spice, the Susie digital simulator, and tools from other major CAE vendors. $295.

Phase Three Logic Inc, 1600 NW 167th Pl, Beaverton, OR 97006. Phone (503) 645-0313.

Circle No. 367

VHDL Library

The VHDL-LSI-001 library contains simulation models of LSI's LCA 10000 macrocells. The macrocells have been modeled in VHDL using the 4-values logic recommended by the VHDL Design Exchange Group (VDEG) to ensure portability among various VHDL simulators.

The models provide accurate propagation delays as a function of the standard load for each output pin, and they supply temperature and voltage tolerances for commercial, industrial, and military specifications. Within each of these three categories, you can specify minimum, nominal, or maximum delays. If you don't supply a parameter at runtime, the model uses the default value.

The library comes with utility programs that implement, in a portable manner, the required functions and procedures. When ordering, specify the VHDL simulator you use; you'll then receive a syntactically correct VHDL library that you can use on your simulator without any modifications. $4950/simulator copy.

EIS Modeling Inc, 2483 Old Middlefield Way, Suite 130, Mountain View, CA 94043. Phone (415) 964-2296. FAX 415-964-0204.

Circle No. 368

Erasable-PLD Design Tool

Max+Plus runs on IBM PC/ATs, PS/2s, and compatible computers that have at least 640k bytes of RAM and a 20M-byte (or larger) hard disk. Version 2.0 of the erasable-PLD design tool includes the company's hardware description language (HDL) and a context-sensitive editor. The tool facilitates the

Text continued on pg 176

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MAP55-4002		5V @ 6A	12V @ 3A/4A PK	12V @ 1A	– 12V @ 1A
MAP80-4000	80W/110W PK	5V @ 14A	12V @ 4A/7A PK	– 12V @ 1A	– 5V @ 1A
MAP80-4001		5V @ 14A	12V @ 1A	– 12V @ 1A	24V @ 2A
MAP80-4002		5V @ 14A	12V @ 4A/7A PK	12V @ 1A	– 12V @ 1A
MAP130-4000	130W/165W PK	5V @ 20A	12V @ 5A/8A PK	– 12V @ 1A	– 5V @ 1A
MAP130-4001		5V @ 20A	12V @ 1A	– 12V @ 1A	24V @ 3.5A
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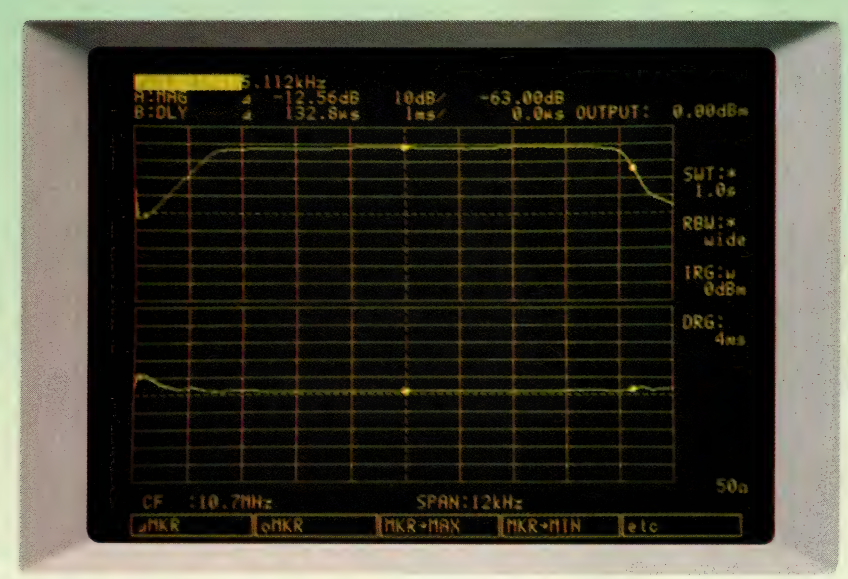

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CIRCLE NO 112

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behavioral specification of complex logic, which is necessary for designs targeted at the vendor's Multiple-Array Matrix (MAX) family of erasable PLDs. A few lines of the HDL code can replace many lines of Boolean equations or an entire state machine.

The HDL also takes advantage of new software features that provide automatic assignment of state variables, automatic error location, and timing-delay verification. The software automatically calls up its text editor when you enter an HDL block and its graphics editor when you enter a schematic. A hierarchy navigator lets you navigate multiple logic levels of a complex design. Each level in the design may have multiple blocks, which you can specify in either HDL or schematic form. PLDS-MAX version, including programming hardware and device adapters for two types of MAX erasable PLDs, $4995; PLS-MAX software-only version, $3400.

Altera Corp, 3525 Monroe St, Santa Clara, CA 95051. Phone (408) 984-2800. **Circle No. 369**

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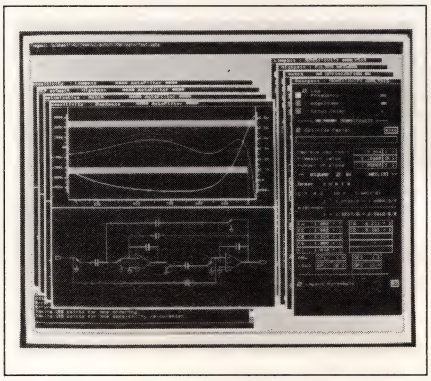


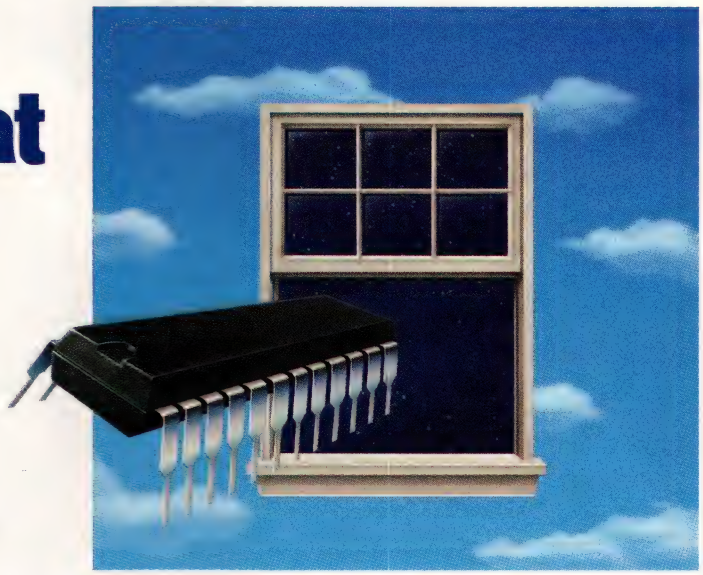
Switched-Capacitor-Filter Design Tool

Explorer AutoFilter performs four key steps in switched-capacitor filter design. In the first phase, you can increase band rejection until you reach the maximum obtainable from a filter of the specified order. In the second phase, you can add, move, or delete poles and zeros to create a specialized response. The third phase orders the biquads to maximize dynamic range and minimize noise sensitivity. The fourth phase calculates the sensitivity of the biquad network to capacitor-mismatch in the manufacturing process.

The program uses a combination of graphic filter-performance capture, synthesis algorithms, and automated layout techniques. Because the program is interactive, you have complete control over all variables that affect performance, and you can explore tradeoffs in your high-level specification. In addition, you can synthesize op amps

Text continued on pg 180

The window of opportunity on TI Advanced Logic products is open wide at Hall-Mark.



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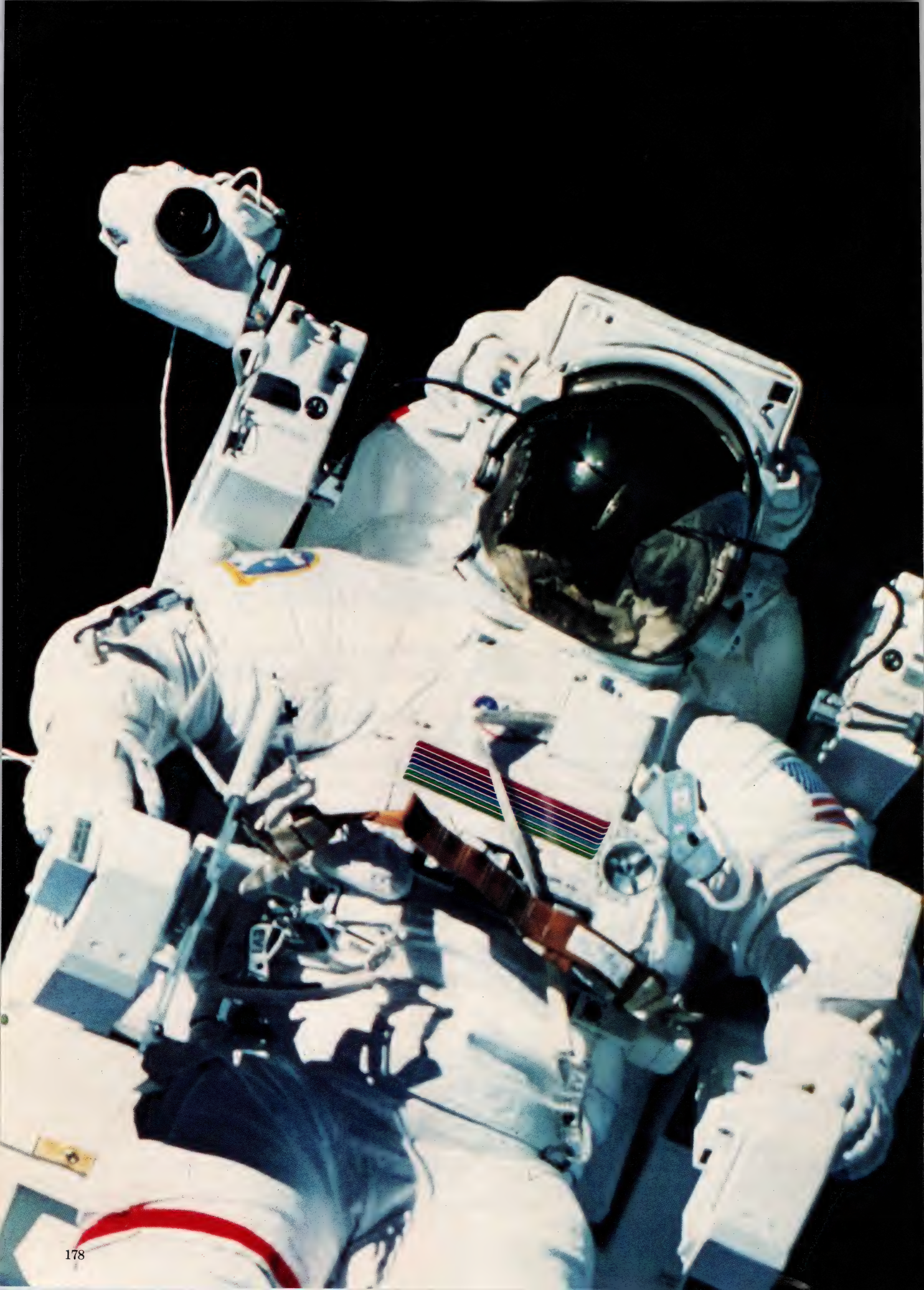

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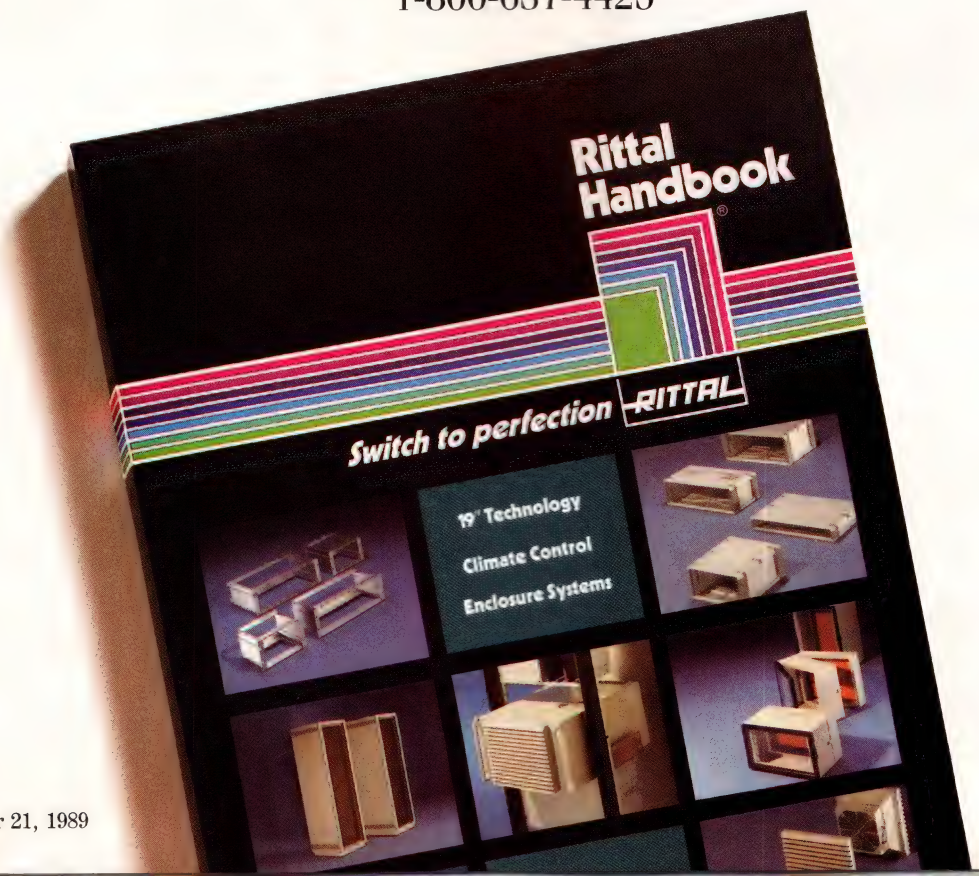

RITTAL Corporation
P.O. Box 1284
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Springfield, OH 45504
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CIRCLE NO 114

to optimize your design for maximum performance, or you can call up existing op amps from a library that provides all of their characteristics. The program is menu driven and guides you through the design steps. It runs on either Sun-3 or Apollo DN4500 workstations. From $40,000.

Silicon Compiler Systems, 2045 Hamilton Ave, San Jose, CA 95125. Phone (408) 371-2900. FAX 408-559-4916. **Circle No. 370**

Module Generator For IC Design

Modules can greatly facilitate changes in your designs, but module generators have thus far required too much programming effort to become popular. The ModuleMaker design tool simplifies the creation of module generators because it eliminates many of the more tedious programming tasks.

ModuleMaker gives you access to all of the vendor's IC design tools and libraries. It offers a diverse set of implementation styles, so you can choose the right technology for each module generator. The generators that you create are more flexible than conventional fixed cells: once you input your parameters, the generators can automate the creation of all cell-library representations and provide means of reusing the resulting modules in other designs. Then, if design specifications change, you don't have to redesign a cell from scratch; you merely adjust the module's parameters and automatically regenerate it using the module generator. ModuleMaker is completely compatible with the vendor's other IC design and verification tools. $90,000.

Cadence Design Systems Inc, 555 River Oaks Pkwy, San Jose, CA 95134. Phone (408) 943-1234. FAX 408-943-0513. **Circle No. 371**

Logic Simulator

Schema-Susie is a comprehensive digital-logic simulator for pc-board designers. The program accepts the net list generated by the vendor's Schema II+ schematic-capture program and simulates the configuration for engineering verification.

You can generate test vectors and evaluate your design either at the board level or section by section. A built-in waveform generator displays the results, and a precise timing analysis, with a resolution of 10 psec, reveals any design problems. When you make changes to correct the problems, you don't have to recompile; your changes are simulated and displayed immedi-

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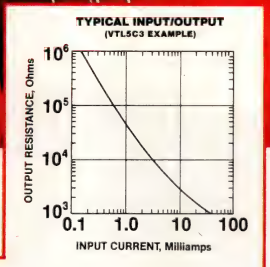

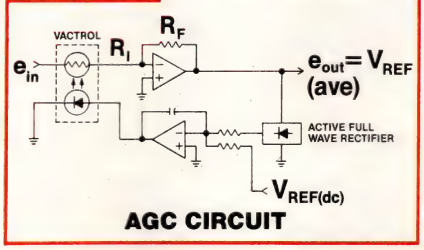

An example of the AGC application and a charactertistic for VTL5C3 are illustrated.

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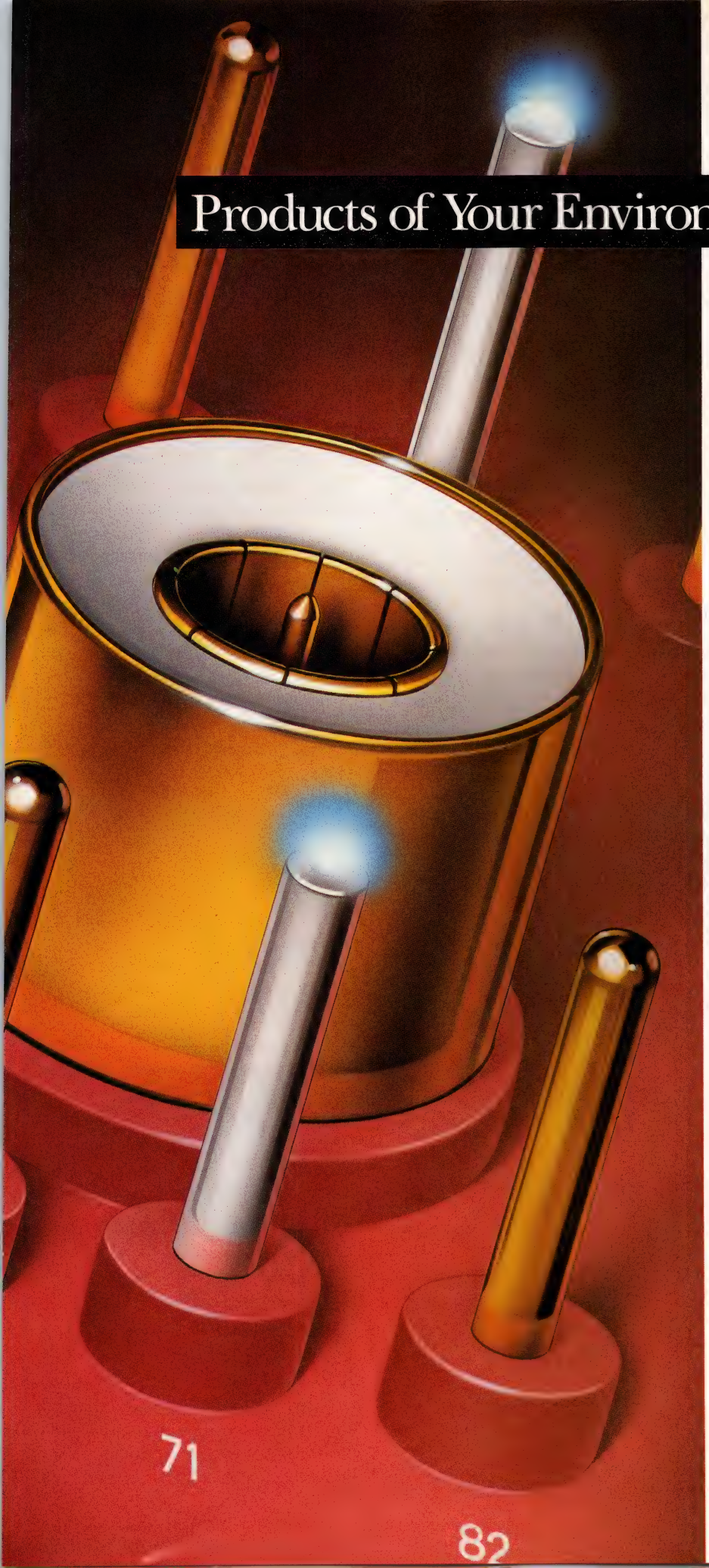

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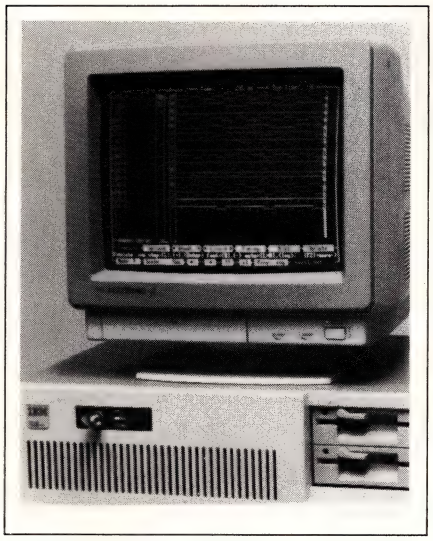


ately.

The simulator can operate in functional mode, which applies no delays; in glitch mode, which applies a standard unit delay to the design; or in timing mode, which applies an appropriate delay to each of the components under analysis. The program runs on IBM PC/XTs, PC/ATs, PS/2s, and compatibles that have at least 512k bytes of RAM and a CGA, EGA, or Hercules graphics adapter card. Schema-Susie comes with TTL-, ECL-, CMOS-, Switch-, and Passive-device functional libraries. Optional libraries are available for PLDs, μPs, controllers, and other devices. $995.

Omation, 801 Presidential Dr, Richardson, TX 75081. Phone (214) 231-5167. FAX 214-783-9072. **Circle No. 372**

IC Layout And Editing Tool

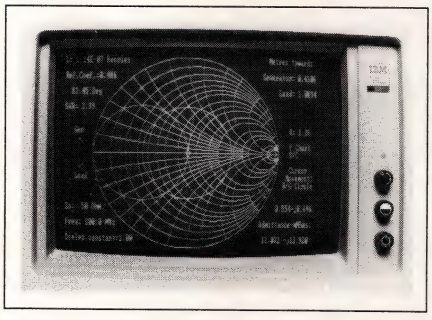
The dw-2000 is a Macintosh-based software package for the layout and editing of IC designs. Release 3.2 incorporates an on-line, design-rule-checking module, Gerber file import and export capabilities, and the ability to create output files for Cambridge EBMF digital-pattern generators.

You can configure the design-rule-checking module for whatever IC technology you are using and then perform interactive and incremental checks throughout the design process. The Gerber file feature supports aperture-wheel plotters as well as laser printers. The Cambridge EBMF output feature lets you create digital-pattern files locally at the dw-2000 workstation, without mainframe-based conversion utilities.

A graphics programming environment lets you create elaborate customized program functions, such as specialized design-rule checking. You don't need any programming ability to use the environment; compatibility with the Calma GPL (graphics programming language) lets you use many existing program libraries.

To run the dw-2000 programs, you need a Macintosh II computer that has at least 4M bytes of memory. $10,500 (single user).

Design Workshop, 4226 St John's Blvd, Suite 400, Dollard des Ormeaux, Quebec H9G 1X5, Canada. Phone (514) 696-4753. FAX 514-696-5351. **Circle No. 373**



RF Design Tool

Z-Match is an RF-design program that runs on IBM PCs and compatibles, and handles the calculation and conversion of impedance and admittance, parallel and series network equivalents, wavelengths, distances, characteristic impedance

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— PC Magazine

For problems involving engineering calculations or scientific analysis, the answer is MathCAD.®

MathCAD is the only PC-based software package specifically designed to give technical professionals the freedom to follow their own scientific intuition. You decide how to solve the problem – MathCAD does the "grunt work."

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To find out what MathCAD can do for you, call us today for a **free demo disk: 1-800-MathCAD** (in MA, 617-577-1017). Or write to MathSoft, Inc., One Kendall Square, Cambridge, Massachusetts 02139.

Requires IBM® PC or compatible, 512KB RAM, graphics card.

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CIRCLE NO 24

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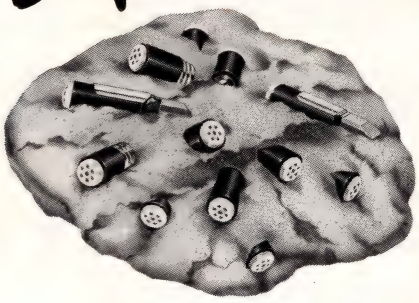
Hamilton Avnet ELECTRONICS AN AVNET COMPANY

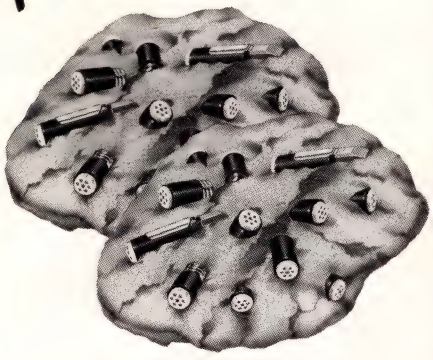
CIRCLE NO 126

HAMILTON/AVNET: THE FIRST NATIONAL DISTRIBUTOR WITH A V.A.D. CENTER CERTIFIED BY INTEL

Experience



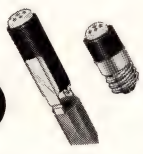
Gourmet Multi-Chips



THE LED ALTERNATIVE TO INCANDESCENT LAMPS

DDP's packaged LEDs are designed as direct replacements for incandescent lamps. Our LEDs provide long life (averaging 10 years or more), and resistance to vibration and shock.

Multi-Chip Features:
- 6-Chip wide angle illuminator
- 160° Viewing angle
- Plug compatible for T1¾ to T3¼ lamps
- Assorted colors & bases
- 5 to 110 Volts



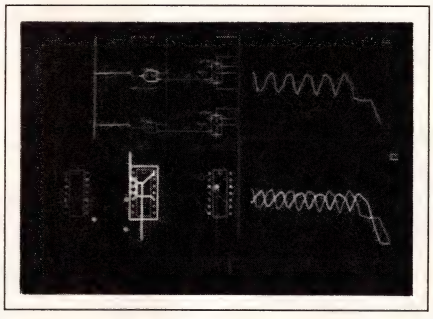
ddp

Data Display Products
445 South Douglas Street
El Segundo, Calif. 90245-4630
(213) 640-0442, Ext. 114
Fax (213) 640-7639

CIRCLE NO 25

(Z_0), dielectric constants, reflection coefficients, standing-wave ratios, and Q values. The program creates a Smith chart based on two sets of circles, one of which represents the resistive component and the other the reactive component. The circular properties of the chart let you make calculations of impedances, admittances, SWRs, and Q values, by simple geometric constructs, and read off actual values at the cursor position. You can directly implement the solutions that you find with the aid of Z-Match with transmission-line transformer and stub-matching methods, using coaxial cables, microstrip, stripline, and waveguides. £130.

Number One Systems Ltd, Harding Way, Somersham Rd, St Ives, Huntingdon, PE17 4WR, UK. Phone 0480 61778. **Circle No. 374**



Analysis Tool

Swiftline is a transmission-line analysis software tool for use on Mentor Graphics pc-board-layout systems. The program extracts layout data directly from the Mentor Graphics layout database; you provide additional information about the layer organization of the pc board and the distances between each layer and the ground plane. The program uses this information, in conjunction with dielectric and component characteristics contained in a built-in library, to identify areas of the board that may give rise to troublesome transmission-line effects such as delays, undershoot/overshoot, and ringing. By taking account of reflections caused by termination impedances and discontinuities caused by junctions, vias, and corners in each net, the program can produce a report of all areas that may cause problems. The program can analyze an entire board, or you can restrict it to selected tracks. $12,500.

Swiftlogic Ltd, Badenheath Pl, Cumbernauld, Glasgow G68 9HX, Scotland. Phone 44 236 720748. FAX 44 236 730983.

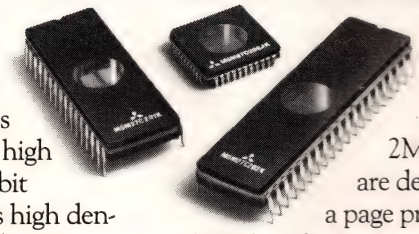
Circle No. 375

Analog Simulator

ACNAP (AC Network Analysis Program) is a general-purpose, circuit-simulation program that analyzes linear circuits with as many as 200 active and passive components. The program performs Bode, Monte Carlo, sensitivity, noise-equivalent bandwidth, component-iteration, spectrum, and worst-case analyses. You can create macros of unlimited length, in which you can embed comments, delays, and pauses, in order to automate repetitive tasks or to set up instructional sequences for training purposes. You can create, combine, and edit component models and circuits, and then save them as single devices in a component library. The program allows such user-defined subcircuits to have as many as seven external connections, so that you can easily model and manipulate very complex types of devices. There are built-in drivers for ImageWriter (dot-matrix) and LaserWriter (laser) printers, and you can obtain an optional plotter driver that will drive most popular color-pen plotters. The program runs on any Macintosh computer that has at least 512k bytes of memory and runs System 3.2 or later, or Finder 5.3 or later. ACNAP, $349.95; optional plotter driver, $95.

BV Engineering Professional Software, 2023 Chicago Ave, Suite B-13, Riverside, CA 92507. Phone (714) 781-0252. **Circle No. 376**

2 Megabit, 100 Nanosecond EPROMs. Available Now. From Mitsubishi.



Now, with Mitsubishi's 2Mb CMOS EPROMs, high performance 16- and 32-bit MPU systems can access high density memory as fast as 100ns. Plus, system current drain and EPROM programming through-put time can be significantly reduced.

Mitsubishi's sub-micron CMOS process technology makes fast, 100ns, 2Mb EPROM production feasible. And, it results in a low, 30mA active (100μA standby) current drain.

The 100ns, 2Mb EPROMs are designed with a page programming algorithm that writes two words (32 bits) simultaneously. That means all bits can be written in about 28 seconds—four times faster than conventional byte mode.

The 100ns, 2Mb EPROMs are the latest in Mitsubishi's expanding EPROM line which also includes 2Mb OTP ROM options in DIP, flat pack and PLCC packaging.

Soon, a ceramic leaded chip carrier (CLCC) will be available that combines the advantages of high memory density, fast access time and erasability/reprogrammability for surface mount applications.

For more information on fast, 2Mb Mitsubishi EPROM's, call now. (408) 730-5900 Ext., 2106. 1050 E. Arques Avenue, Sunnyvale, CA 94086.

MITSUBISHI ELECTRONICS

CIRCLE NO 117

Next-generation analog: Advanced Linear ICs

A new breed of linear chips, born of leadership processing at Texas Instruments, can help you design superperformance systems.

Sophisticated design and simulation tools shorten development cycles of TI's Advanced Linear ICs, helping you get to market faster. By using these tools, TI can offer as standard circuits many designs that previously would have had to have been customized.

The human brain has separate but dependent left and right sides. Similarly, an electronic "brain" or system has separate but dependent parts, one digital, one analog. Designers accustomed to the spectacular performance gains made in digital chips are now demanding comparable improvements in analog devices so that both parts of their systems can function to full potential. Leading the analog evolution: Advanced Linear circuits from Texas Instruments.

These new chips are called *advanced* for one or more reasons. They are more highly integrated than ever before, often combining digital and analog functions on a single chip. They offer higher performance and greater flexibility. They are often the result of advanced processing that may merge two or more technologies.

Better parameters from better processing

Because advanced analog system requirements for performance and flexibility vary greatly, a single workhorse technology typically can't do the job any longer. Nor can creative circuit designs alone. We at TI are convinced the key to driving the linear evolution lies in the excellence of our processing technologies.

TI is committed to developing and implementing a range of leadership wafer-fabrication processes (*see descriptions on back page*). The result: TI's Advanced Linear devices are already helping system designers link digital brains to advanced analog worlds more efficiently and with greater ease in many applications. Here are a few examples.

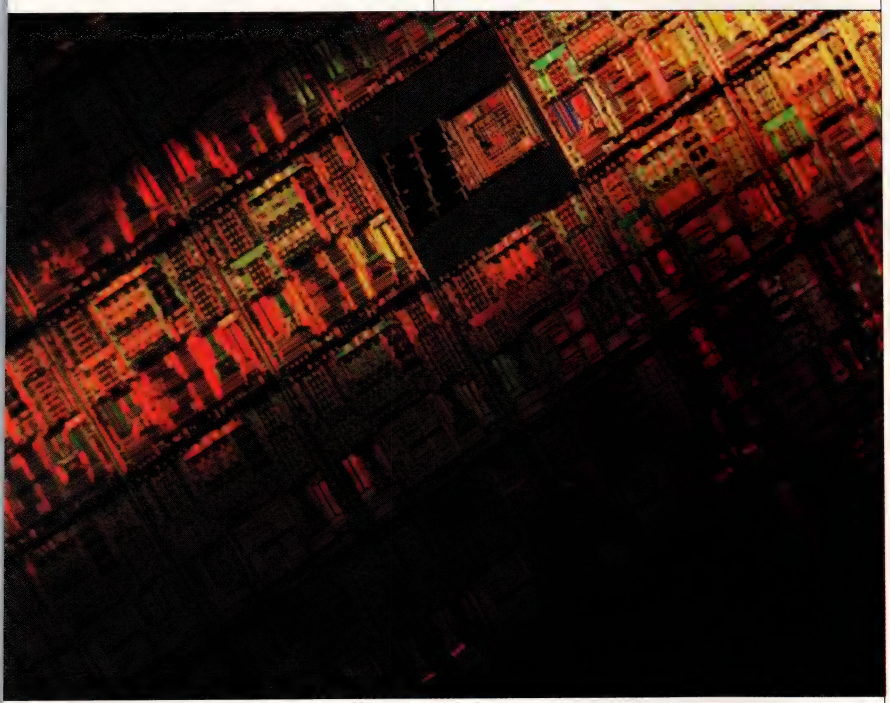
Advanced Linear: Displaying greater brilliance

Out of our pacesetting LinEPIC™ processing comes our high-performance Color Video Palette, operating at 125 MHz with a very high-resolution 1024 x 1024 pixel count. Because of one-micron CMOS processing, power consumption is reduced more than 40% compared to other CMOS implementations. Additionally, the device is pack-

...the key to driving the linear evolution lies in the excellence of processing technologies.

aged in reliable, economical plastic.

LinEPIC has also produced such high-speed, high-density interface chips as our Flash A/D and our Video DAC for use in graphics displays, imaging systems, monitors, and cameras. Both devices require about five times less power than bipolar equivalents.



High-density Analog Interface Circuit chips demonstrate the greater integration achieved by TI's innovative linear processing technologies. These DSP interfaces allow you to alter circuit configuration under software control without external adjustments.

Advanced Linear: Intelligent power for every car

Chips fabricated with our Power DMOS-based BIDFET™ processing are replacing electromechanical relays in many automotive applications, such as driving headlamps and motors. Power BIDFET allows us to minimize power loss in the switch and add high-complexity logic functions.

Multi-EPI bipolar processing, a very cost-effective technology, is used to produce chips having inherent reverse battery protection and high operating voltages. Such chips are ideal for use in automotive antilock braking systems, electronic transmissions, and active suspension systems.

Either technology can produce devices with low-side drive, high-side drive, or H-bridge configurations.

In the future, these developments may lead to multiplexed systems for cars, replacing bulky wiring harnesses.

Advanced Linear: Enhancing modems and facsimiles

TI's dual driver/receiver is a good example of the integration achieved with advanced processing technologies. LinBiCMOS™ processing has enabled us to put the drivers and receivers needed for RS-232 voltage levels on the same chip with the charge pump required to generate the necessary split rails from a single 5-V supply. You eliminate external power supplies and get a device that's easier to design with—it is available in our LinASIC™ cell library for integration with digital ASICs.

A new family of Analog Interface Circuits (AICs) is emerging from our Advanced LinCMOS™ processing. The voice-band AICs, designed for modems and fax equipment, combine high-performance analog functions—14-bit A/D and D/A converters and switched capacitor filters—with digital functions such as control circuitry, program registers, and DSP interface. The usual clutter of resistors, capacitors, and pots is eliminated.

High-speed AICs are available for use in servo controllers and hard-disk-drive applications.

These AICs are also high-performance members of our LinASIC standard-cell library. Based on TI's proven digital ASIC methodologies, the LinASIC library has allowed us to develop complex, semicustom chips in as little as 16 weeks.

Advanced Linear: Boosting instrumentation accuracy

Even one of the most basic analog building blocks, the operational amplifier, is benefiting from TI's Advanced Linear technologies. Our Excalibur op amp family combines low power consumption with a 5X speed improvement while retaining low offset voltages. Offset-voltage drift has been cut from 300 μV to 60 μV to reduce your calibration, test, and measurement expenses.

For high-accuracy applications, Advanced LinCMOS is making possible Chopper Stabilized Op Amps with chopping frequencies 10 times higher than previously available (10 kHz). Noise levels are the lowest on the market.

Our just-published *Advanced Linear Circuits* brochure examines more fully the changes taking place in analog system design and their impact on linear devices. The brochure also describes TI's leadership processing technologies and explains the performance improvements that result. **For your copy, call 1-800-232-3200, ext. 3407, today.**

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TEXAS INSTRUMENTS

RACK 'EM UP

Did you know that only one power supply company can "rack-up" a complete line of switching-regulator power supplies? That's right. Only Power Ten offers you the full range of rack-mount switchers—from 1-10 kw with over 85 standard current and voltage combinations.

But you get more than just a wide range to choose from when you choose Power Ten. A lot more.

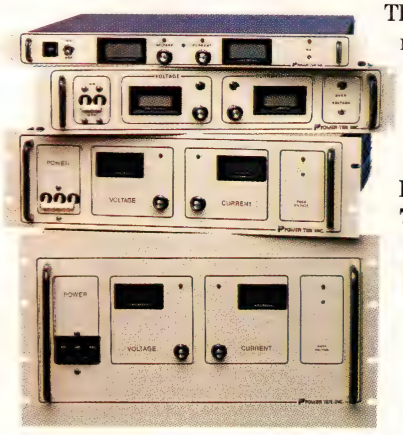
- Full 5-year warranty.
- Operating efficiency: 85%+ across full operating range.
- Transient response to step load change: 2 msec.
- Over-voltage protection: Fully adjustable 0-110%.
- Performance derating over ambient temp (0-50 Deg C.): None
- Output current monitor: 0-5v or 0-1ma signal = 100% output
- Auto serial/parallel: Yes, including auto load share.
- AC power line noise: No, suppressed by internal filter.
- Output meters: Digital, can be field calibrated.

Power Ten was first to offer commercial, rack-mount switchers. And we're still the leader in range of products, price and performance. For example, only Power Ten's Series 4500, 4600 and 4700 supplies offer user-installable power modules. That makes maintenance easy (MTTR <30 minutes) and lets you customize them yourself as requirements change.

What's more, Power Ten supplies are lighter so installation is easier. They're smaller so they take up less rack and floor space. And they run cooler so you save on air conditioning.

Call or write, today. We'll rush you our new brochure and product specs. Then you'll understand why Power Ten power supplies offer you the best. The best range. The best performance. And the best price.

If you don't, you might find yourself behind the eight ball.



Power Ten Inc., 486 Mercury Dr., Sunnyvale, CA 94086, (408) 738-5959, Fax (408) 738-4326.

POWER TEN INC.

CIRCLE NO 118

Catalog details dc/dc converters

This catalog covers both dc/dc converters and encapsulated, modular ac/dc power supplies. The two sections each contain a "Quick Locater" guide that arranges the devices in easy-to-read tables according to input voltage or type of output, output voltage, and output power. Following the guides are detailed specifications of each unit, including photos, schematics, and graphs to further illustrate the company's line. The 68-pg catalog also describes two dc/dc converters with special characteristics: the I60S5.135 with full-load efficiency of 78% for a 0.7W output; and the 12Q15.050 with dual-output sections that are fully isolated from each other and from the common input to provide the required noninteraction between output channels. Case sizes and mounting-kit descriptions for the converters and supplies complete the catalog.

Calex Mfg Co Inc, 3355 Vincent Rd, Pleasant Hill, CA 94523.

Circle No. 403

Linear and custom power supplies on disk

This catalog on a disk describes a complete linear product line, including standard, custom, and tailored combinations, as well as ferroresonant and unregulated power supplies. The publication presents more than 10,000 products in a few simple tables. The 5¼-in. floppy-disk catalog runs on IBM PCs and compatibles and features pop-up help screens.

Xentek Inc, 760 Shadowridge Dr, Vista, CA 92083.

Circle No. 404

App note explains dc/dc power converters

This 24-pg application note addresses the basics and historical background of integrated-magnetic switch-mode dc/dc converters. The document addresses fundamental design methods for combining high-frequency transformers and filter inductances on single magnetic-core structures. The note also presents a survey of applications of integrated magnetic principles in PWM converters and resonant-converter circuits. The publication provides extensive references for magnetic design techniques.

E J Bloom Associates Inc, Product Engineering Div, 4340 Redwood Hwy, Suite E356, San Rafael, CA 94903. **Circle No. 405**

Your product looks good longer, for less, with Oak rubber keypads.

Finally! Conductive and non-conductive rubber keypads that meet the long life and reliability of conventional switches. Oak's rubber keypads give you:

An **expensive look** for your product at a **lower cost** than other technologies. With **greater durability** than ever before.

Now you can have silicone rubber keypads that perform up to 5 million cycles depending upon stroke, key pressure and snap effect. With a U.L. rating of 94-V0; operating temperatures from –40°C to +85°C; resistance to weather, corrosion, bacteria and puncture; and custom color combinations including translucent for backlighting. Think of all the possibilities for **your** product applications!

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Phone 815/459-5000

OAK *Your Partner in Excellence*

CIRCLE NO 27

The Quality Goes in Before the Power Switches On... and On...

Zenith announces a dynamic family of standard switching power supplies ranging from 150 to 400 watts. Our power supplies deliver exceptional quality, reliability and flexibility for a variety of design applications.

Model	Max Output Power (Watts)	Main Output Volts DC (Nominal)	Main Output Amps (Min/Max)	2nd Output Volts DC (Nominal)	2nd Output Amps (Min/Max)	3rd Output Volts DC (Nominal)	3rd Output Amps (Min/Max)	4th Output Volts DC (Nominal)	4th Output Amps (Min/Max)
ZPS-150	150	4.75/5.25	2.0/20.0	10.0-15.0	0.3/3.0 PK 4.5	10.0-15.0	0.3/3.0 PK 4.5	4.75/5.25	0.2/2.0
ZPS-175	175	4.75/5.25	2.5/25.0	10.0-15.0	0.3/3.5 PK 5.3	10.0-15.0	0.3/3.5 PK 5.3	4.75/5.25	0.2/2.0
ZPS-200	200	4.75/5.25	3.0/30.0	10.0-15.0	0.4/4.0 PK 6.0	10.0-15.0	0.4/4.0 PK 6.0	4.75/5.25	0.2/2.0
ZPS-250A	250	4.75/5.25	3.5/35.0	11.5-26.0	0.4/4.0 PK 6.0	4.75-16.0	0.4/4.0 PK 6.0	4.75-16.0	0.3/3.0 PK 4.5
ZPS-300A	300	4.75/5.25	4.5/45.0	11.5-26.0	0.6/6.0 PK 9.0	4.75-16.0	0.8/8.0 PK 12	4.75-16.0	0.4/4.0 PK 6.0
ZPS-400A	400	4.75/5.25	5.5/55.0	11.5-26.0	0.7/7.0 PK 10.5	4.75-16.0	1.0/10.0 PK 15.0	4.75-16.0	0.6/6.0 PK 9.0

Zenith power supplies provide a wide range of user-adjustable voltage settings.

Typical Voltage Settings For
ZPS-250A, ZPS-300A and ZPS-400A

MAIN	CH. 2	CH.3	CH.4
5	12	12	5
5	12	12	12
5	15	15	5
5	24	12	5
5	24	12	12
5	24	15	15

And Many More Configurations!

- All outputs fully regulated.
- UL/CSA/IEC/VDE Agency Approvals for Safety and EMI
- 2-year warranty backed by Zenith
- 100,000 - 150,000 MTBF

ZENITH components

The quality goes in before the name goes on®

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1000 Milwaukee Avenue
Glenview, IL 60025-2493

FOR MORE INFORMATION CALL: 1-800-827-8720

CIRCLE NO 119

"Static can kill our circuitry. And the front panel LEDs can provide the path. Now what?!"

All indications are Dialight.

It was a problem grounded in the laws of electrical energy. And it could have caused real havoc. But the customer took the smart step of calling Dialight.

As the leader with over half a century of experience in every type of indicator light, for Dialight solving problems is standard operating procedure. Applying our engineering expertise in optoelectronics and utilizing state-of-the-art CAD equipment, our model shop quickly developed and prototyped a housing and grounding plate for the LEDs. Upon customer approval, our 100% internal tool fabrication and molding facilities provided quick turn-around on production quantities.

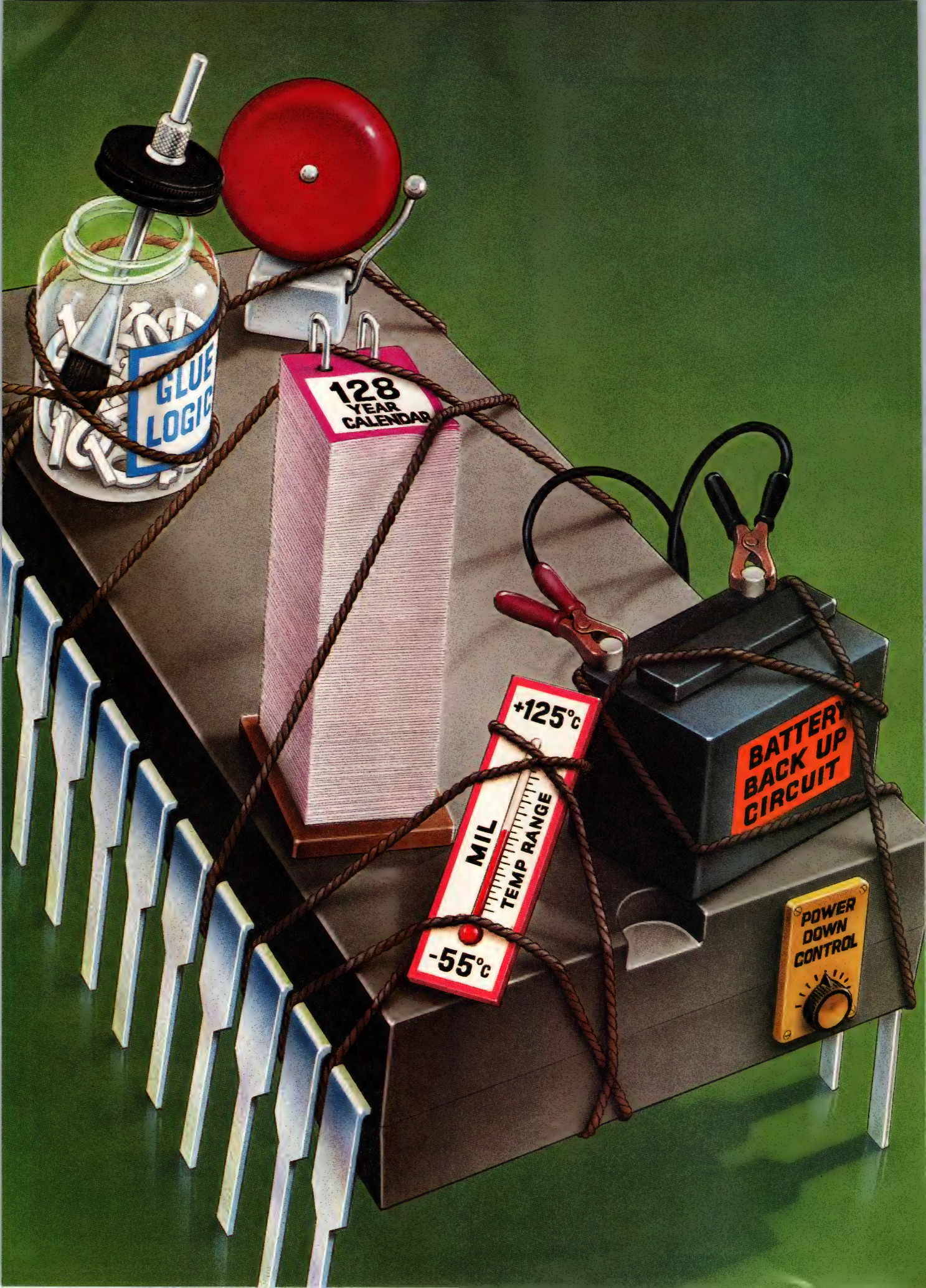
Saving costs while solving problems is something we've long done with our panel mount and circuit board LEDs. Over the years customers have asked us to pair, gang, piggyback, right angle mount, recess, bicolor, tricolor, slant, standoff, snap-mount, bin, do whatever you can imagine to them and we haven't been stumped yet!

So, when an indication design issue has you ground to a halt, remember that no one has more solutions than Dialight.

DIALIGHT CORPORATION
A Cambridge Electronic Industries Co.

1913 Atlantic Avenue, Manasquan, NJ 08736 201-223-9400

CIRCLE NO 122


GLUE LOGIC
128 YEAR CALENDAR
+125°c
MIL TEMP RANGE
-55°c
BATTERY BACK UP CIRCUIT
POWER DOWN CONTROL

Next time they boast about adding more features to a real-time clock, ask to see one first.

The Harris Way: More On-Chip Functions And Affordable.

First, we thought about life two centuries from now. Then we built a clock to last that long.

A 128-year calendar with automatic leap year corrections is just one impressive feature of our patented ICM7170 real-time processor-compatible clock. There are many more.

Our CMOS-fabricated clock offers more on-chip functions than commodity-quality clocks, including a battery backup circuit, regulated power supply (assuring stable oscillator frequency), on-chip power down detector and on-chip alarm comparator and RAM. It generates alarm interrupts and seven programmable periodic interrupts.

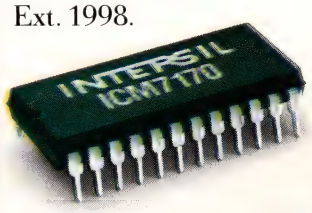
Eight separate internal addressable and programmable counters keep time from hundredths of seconds to years. The ICM7170 is easy to use, too: no exotic software is needed. Latches prevent clock roll-over during read cycle. And you read it like a RAM.

The 7170's 300 ns access time and high compatibility make it a perfect peripheral for a whole range of applications, from data logging and portable and personal computers to industrial process control and point of sale systems.

With its military temperature rating and 883C screening, the ICM7170 is already performing where performance counts most — in demanding strategic and tactical systems. Packages include 24-pin plastic and ceramic DIPs and 24-pin small-outline DIP.

So if you're looking for a high-performance power-saving clock for your system, look to Harris' 7170.

Call for our brochure and data sheet: 1-800-4-HARRIS, Ext. 1998.



What your vision of the future demands. Today.

HARRIS SEMICONDUCTOR

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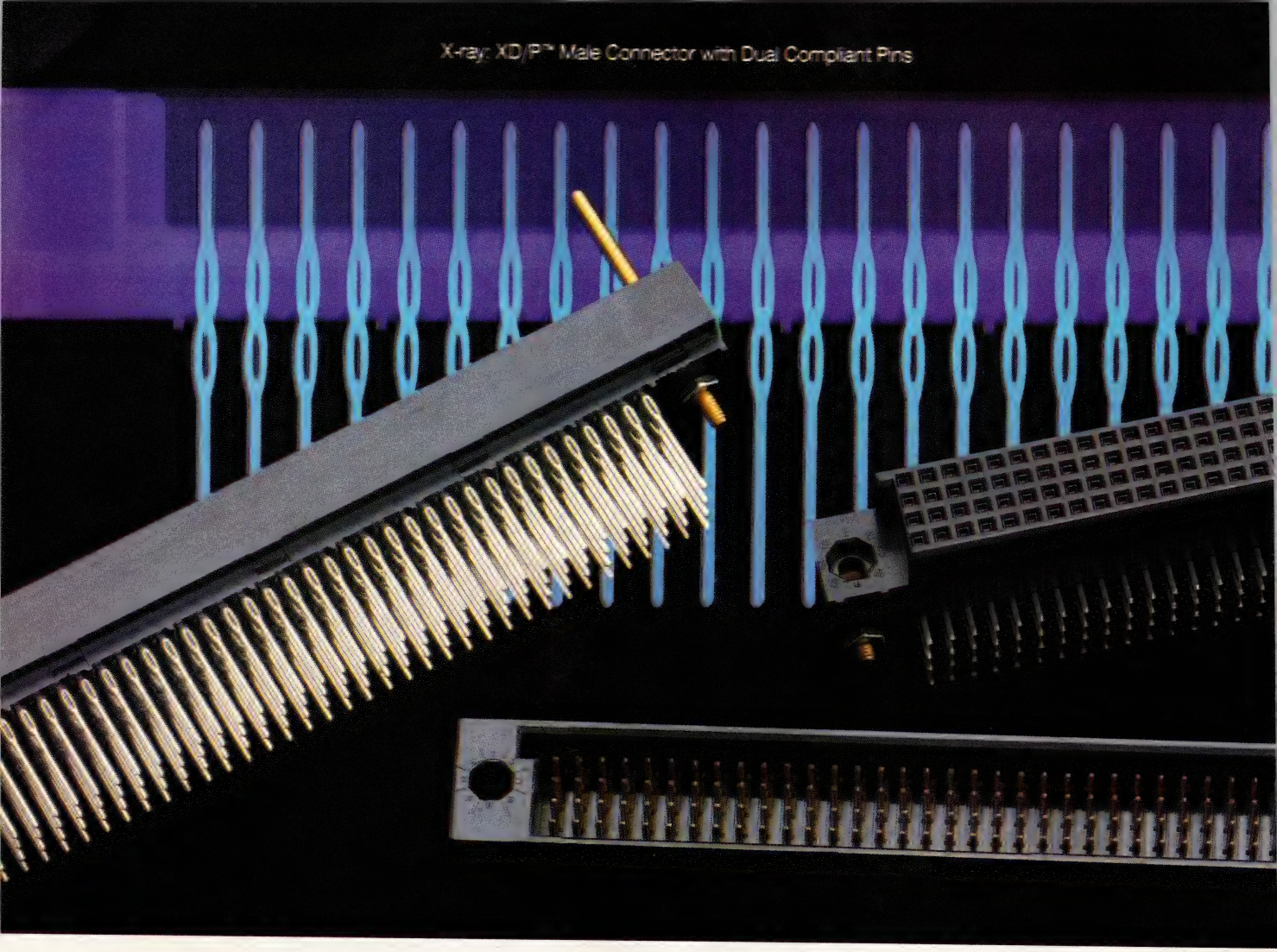
CIRCLE NO 123



A revealing look at the difference in high density PCB connector systems.

The X-ray of our XD/P™ high density PCB connector emphasizes that what's **inside** a connector makes the difference — in performance, reliability, and installed cost.

To help you make the best choice in PCB connector systems, we offer a close look at our XD/P™ connector line, with up to 684 positions. Feature for feature, we invite comparison.

Made straight to mate straight

- Stress-free molding eliminates warping in large connectors.
- .114″ nominal engagement length of pin and socket ensures reliable mating.

A perfect fit for any board

- FLEX-FIT™ compliant pin fits board thicknesses of .062″ to .125″ for high density multi-layer PCB designs.
- FLEX-FIT™ dual compliant pin design allows **front** or **rear** removal and replacement.

Easier board-to-board insertion

- Unique contact geometry reduces per contact insertion force to 1.5 oz. (avg.), but maintains high normal force of 75 g. (avg.).

Multiple contact and hardware options

- The XD/P™ connector line includes plating, signal, and hardware options to satisfy virtually any requirement.

The company behind the product

A close look at our company will reveal our strong financial position, our commitment to the future, and our ability to support you worldwide. Write for our Annual Report — it's like an X-ray of our company.

To take a close look at our comprehensive XD/P™ connector line, and for the location of our nearest stocking distributor, call

1-800-344-4744.

Thomas & Betts Corporation, Electronics Division,
1001 Frontier Road, Bridgewater, NJ 08807, 201-685-1600

Thomas&Betts

Thomas & Betts facilities in **Australia:** Wyong North N.S.W., 43 53 2300; **Canada:** Ontario, 416-858-1010; **France:** Rungis Cedex, 1-46 87 23 85; **Hong Kong:** Kowloon, (852) 3-7391286; **Italy:** Milan, 02-61 20 451; **Japan:** Tokyo, 3 791 6411; **Mexico:** Naucalpan, 905 393 85 10; **Singapore:** 747 0244; **Spain:** Barcelona, 03-3 00 22 52; **Sweden:** Upplands Vasby, 07 60-8 81 10; **Taiwan:** Taipei, 2 713 0509; **United Kingdom:** Dunstable 0582-608101; **West Germany:** Egelsbach, 0 61 03-40-40.

Data book catalogs communications ICs

In addition to its usual line of communications ICs, the company's 1990 Data Book contains eight new products, as well as several new applications-oriented sections. The 624-pg book lists the K-Series family of modem ICs, modem-support and tone-signaling devices, and telephone/digital telecommunications circuits. Also included are the company's custom and semicustom capabilities, its quality-assurance and reliability program, packaging and ordering options, and a listing of sales offices and distributors.

Silicon Systems, 14351 Myford Rd, Tustin, CA 92680.

Circle No. 398

Selection of signal-processing products

The company's 89/90 Product Selection Guide allows an at-a-glance referral to more than 100 of its most popular signal-processing and power products, including op amps, S/H amps, ADCs, flash A/D subsystems, DACs, data-acquisition systems, voltage references, interface products, analog ASICs, and dc/dc power converters. The publication emphasizes the traditional high-performance hybrid converters and data-acquisition systems, as well as the introduction of monolithic products, such as the op amp series of 2400, 2500, and 2600 products and the SP111 ultra low-noise op amp. Also included are the interface products family, offering a complete set of Maxim's MX23x pin-compatible line of drivers and receivers, as well as the vendor's SP301 and SP302 family, featuring user-selectable RS-232C and RS-422 configurations.

Sipex Corp, 6 Fortune Dr, Billerica, MA 01821.

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And with our lamps, we give you solid-state-of-the-art construction backed with our Loctite applications know-how. So for solutions to any problem, we're here. To learn more, send for our DESIGN GUIDE, the definitive reference on electroluminescence. Because the solution to your lighting problem may be as simple as seeing it in a new light.
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FAX (603) 448-3452, TWX 710-366-0607
Etna Rd., Lebanon, NH 03766
CIRCLE NO 28

Catalog of enclosures on floppy disk

The vendor's 304-pg enclosures catalog is now available on an IBM PC-compatible floppy disk. The resource provides information on modular cabinets in vertical- and slope-front consoles, computer furniture, and many options. On-screen prompts let you select the type of enclosure and options you want. You can then print out the data and send it by facsimile or mail to the vendor, who will respond with a price quote or other requested information.

Equipto Electronics Corp, 351 Woodlawn Ave, Aurora, IL 60506.

Circle No. 400

What you need for computer/electronic repair

A 66-pg catalog presents tools and equipment for computer and electronic repair. Among the product listings are breakout boxes; interface testers; connector kits and tools; static-control wrist straps; oscilloscopes and replacement scope probes; and DVMs and accessories. The extensive coverage includes product descriptions with illustrations and detailed price information.

Specialized Products Co, 2117 W Walnut Hill Lane, Irving, TX 75038.

Circle No. 401

Two publications focus on connectors

The company's 6-pg pamphlet examines front-repairable connectors, high-reliability EMI/EMP (electromagnetic pulse) protection devices that allow access to the active EMI/EMP devices from the front of the connectors for repair. Illustrations provide dimensions for certain connectors with various EMI/EMP protection devices. The pamphlet also includes descriptions, specifications, and charts. Also available is the company's data sheet on programmable EMI/RFI connectors. The data sheet describes the programmable connectors and lists specifications for performance characteristics and diode-connector characteristics at 25°C.

Amphenol Corp, Bendix Connector Operations, 40-60 Delaware Ave, Sidney, NY 13838.

Circle No. 402

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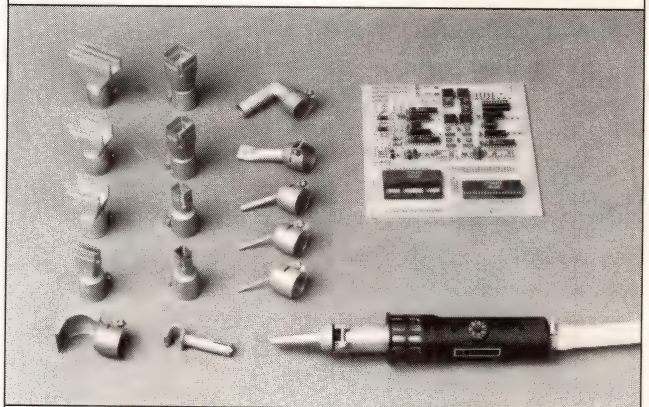

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CIRCLE NO 30

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For more information about the precision flat glass displayed in hundreds of products worldwide, call us at 607-974-4308. Or write: Precision Flat Glass, Corning Incorporated, MP 21-3-1, Corning, N.Y. 14831. And let's get on with the show.

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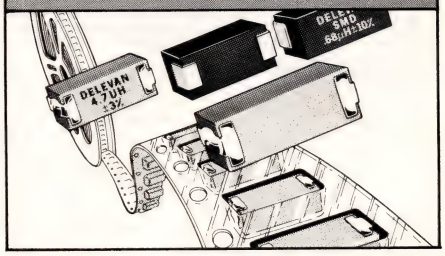

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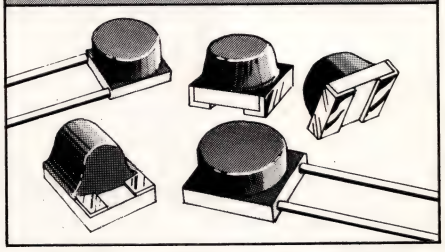

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CIRCLE NO 124

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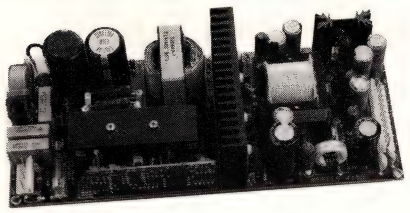

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Other models are available with voltage combinations of 5, 9, 12, 15 & 24 VDC.

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CIRCLE NO 32

LITERATURE: SOFTWARE

Ansys tutorials and summary available

Nine tutorials delineate the features of the Ansys program, revision 4.4, as well as the 1989 2-volume set, *Ansys Conference Proceedings*, which contains 96 of the 99 technical papers delivered at the 4th International Ansys Conference. The tutorials discuss the Ansys finite-element-analysis program, and topics include nonlinear dynamics, acoustics, a 4-node shell element coupled with field analysis, postprocessing, and solid modeling. The conference proceedings deal with Ansys applications in the aerospace, automotive, and electronics businesses; interfaces to CAD programs; university projects; and management and legal issues. Tutorials, $8 to $20; entire set, $60; proceedings, $60.

Swanson Analysis Systems Inc, Box 65, Houston, PA 15342.

INQUIRE DIRECT

Details on programming a network interface card

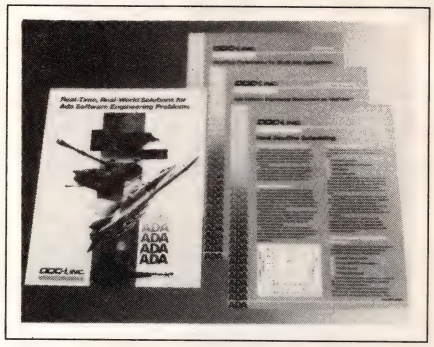
The vendor's application note, Ziatechniques 6, "Developing software for an Arcnet network interface," tells you how to program an Arcnet interface board. The 10-pg note contains detailed code examples and timing calculations.

Ziatech Corp, 3433 Roberto Ct, San Luis Obispo, CA 93401.

Circle No. 406

Packet describes Ada solutions

A 5-pg folder and three technical data sheets provide information on Ada software. *Hard Deadline Scheduling in Ada* looks at research conducted at Carnegie-Mellon University and how it will affect the Ada programming language. *Ada Software Engineering Environment for VAX/VMS* examines various development tools to solve Ada software-engineering problems.



Real-Time Performance for 80×86 Ada Applications analyzes how to enhance hardware performance and minimize software development and cost.

DDC-I Inc, 9630 N 25th St, Suite 118, Phoenix, AZ 85021.

Circle No. 407

Microprocessor manual illuminates software tools

The vendor's latest user manual details software development tools for embedded microprocessor systems. The multicolor publication comes in a 3-ring binder that features pockets in the front and back for document storage.

Introl Corp, 647 W Virginia, Milwaukee, WI 53204.

Circle No. 408

Programming with IEEE-488 software explained

Programming with NI-488 Software explains the philosophy, structure, and features of the company's NI-488 software. The 8-pg note helps users improve the performance of controlling instrumentation and minimize application development time. Several time-saving utilities described include an interactive control program, a configuration utility, the universal language interface for HP-style calls, and diagnostic programs.

National Instruments, 12109 Technology Blvd, Austin, TX 78727. **Circle No. 409**

How to get 32-bit Cache into a restricted area:

Running out of board space? Here is high-performance SRAM, organized for 32-bit systems, with density that delivers up to 80% savings in real estate. Call today for a FREE mechanical sample.

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Here are five very fast ways to simplify the implementation of 32-bit SRAM for high performance applications like RISC and DSP.

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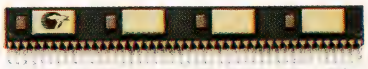

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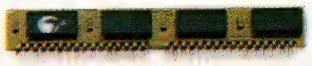

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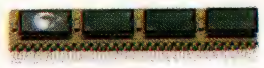

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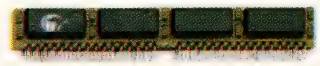
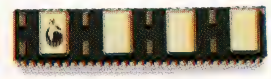


4. CYM1831PZ–64K x 32 SRAM w/$\overline{OE}$, 25ns. 64-pin ZIP. 1.2" Sq. req.



5. **Mil-Spec!** CYM1830HD–64K x 32 SRAM, 25ns. 60-pin DIP. 1.8" Sq. req.

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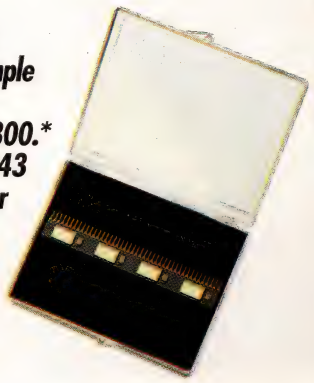

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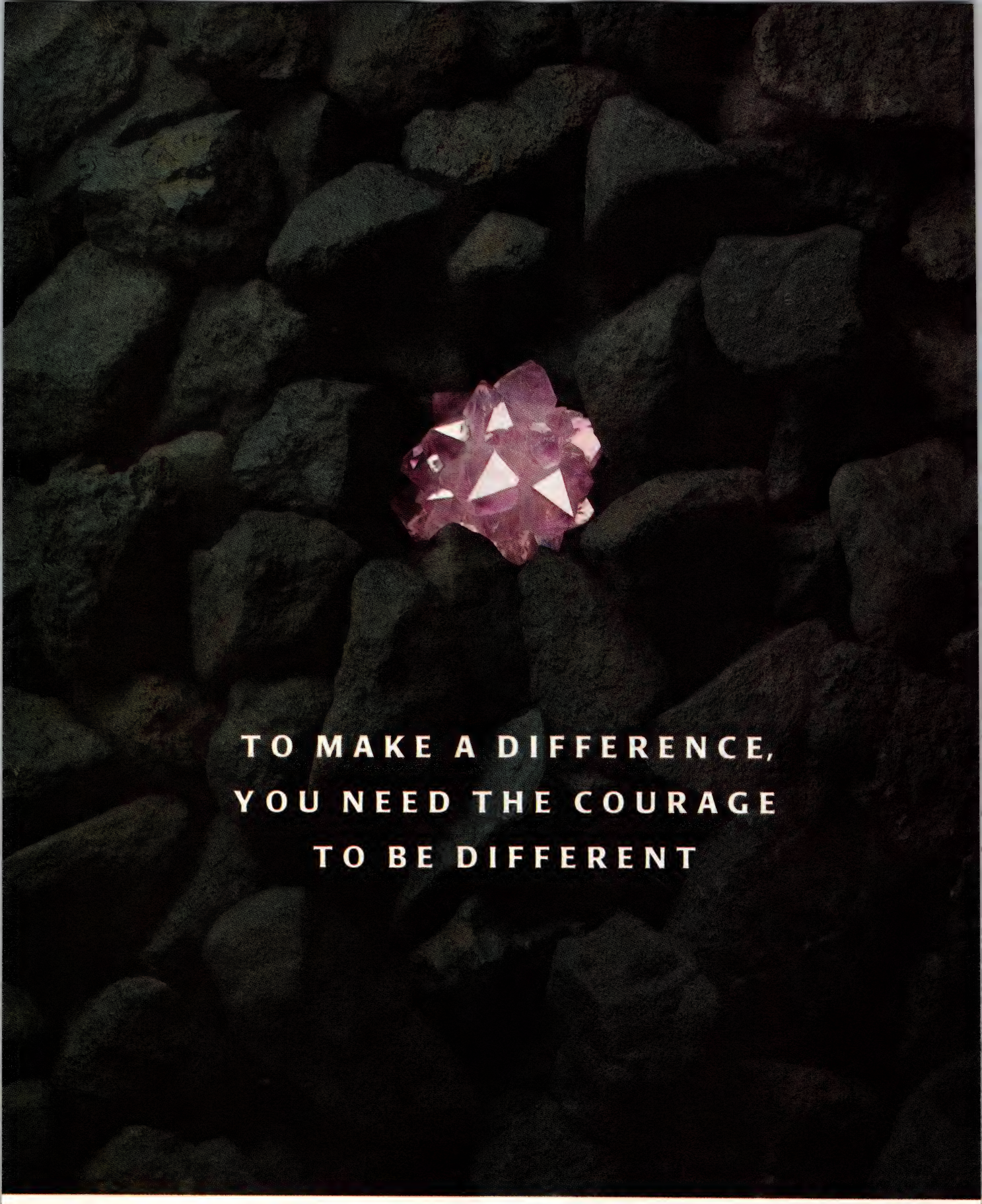

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NEC

CIRCLE NO 125

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But we don't stop there. TOKIN **SMD (Surface Mount Devices) Transformers** can be designed for a vast range of functions and purposes, from high density mountings, to low height installations, DC-DC converters and pulse transformers. All part of our never-ending search for the best materials, most innovative designs and the ideal magnetic circuit.

TOKIN. The cutting edge in transformer technology.

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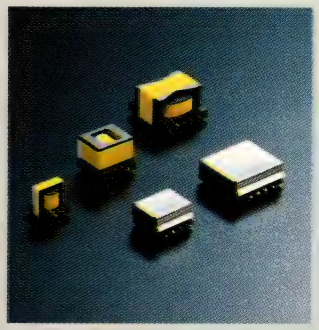

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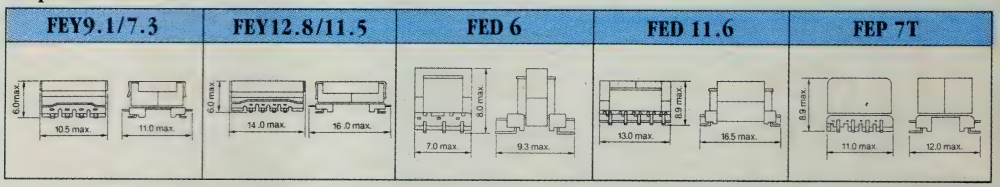

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CIRCLE NO 116

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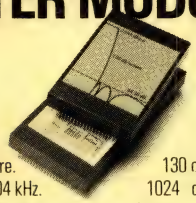

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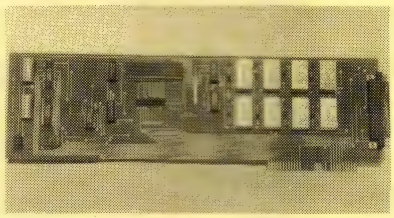

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CIRCLE NO 326

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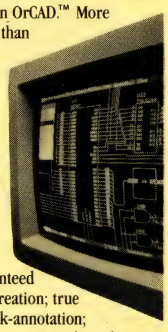

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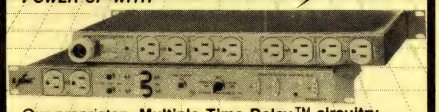

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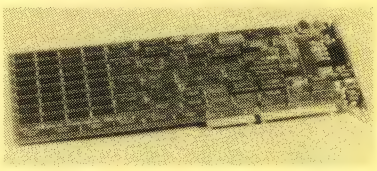

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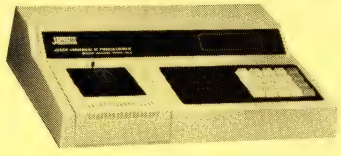

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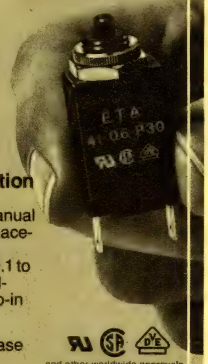

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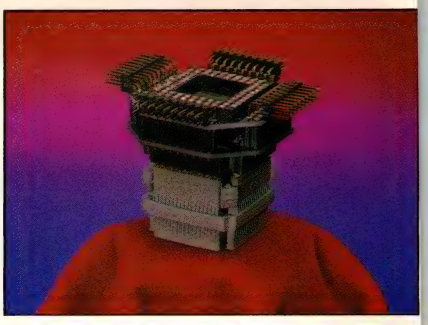

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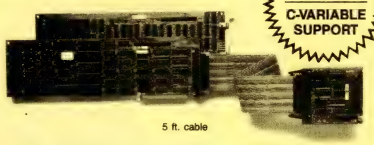

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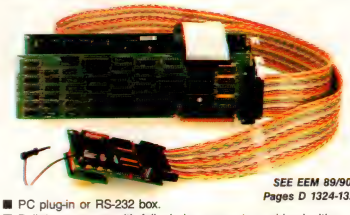

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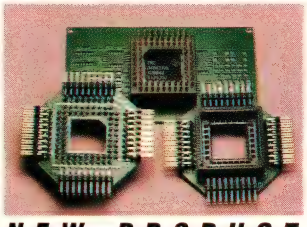

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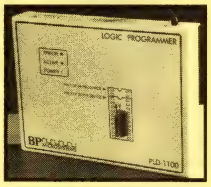

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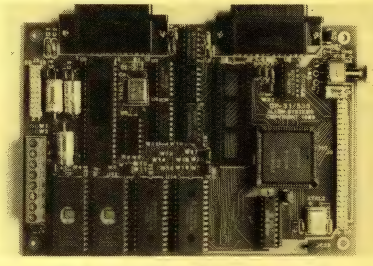

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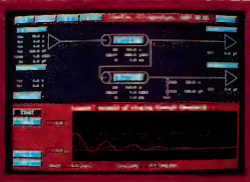

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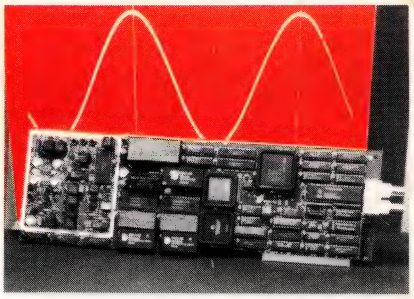

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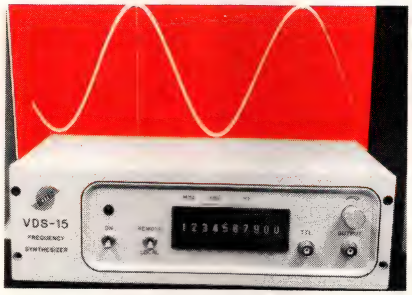

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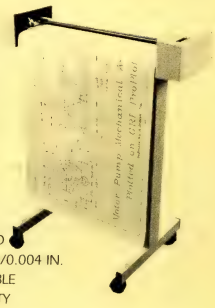

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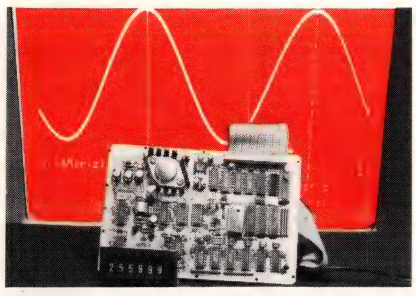

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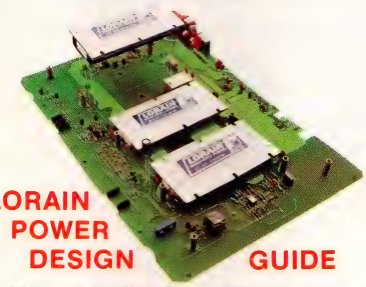

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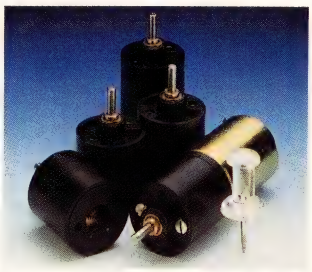

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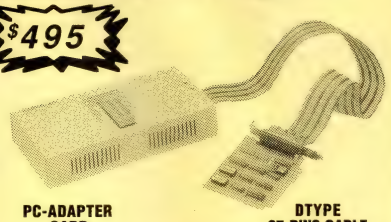

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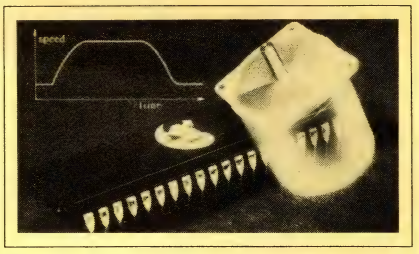

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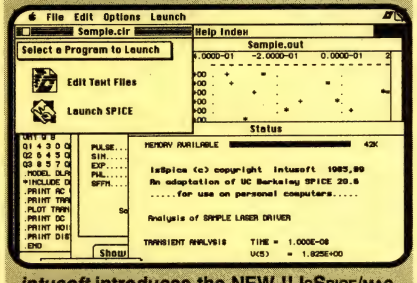

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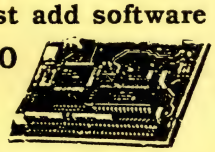

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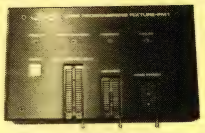

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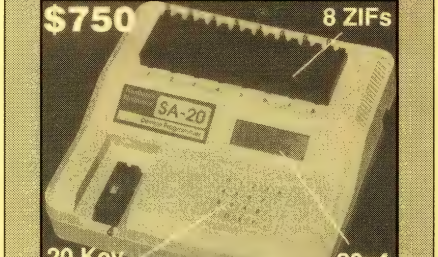

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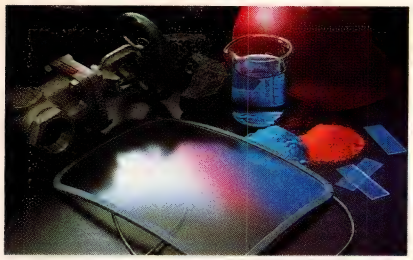

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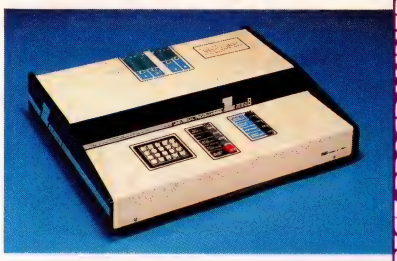

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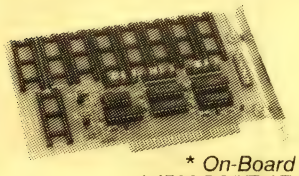

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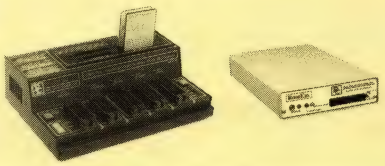

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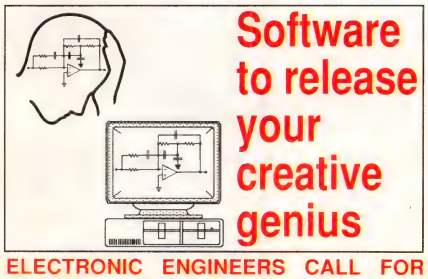

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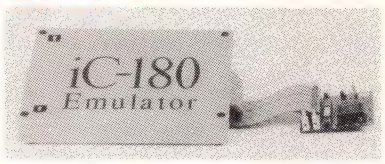

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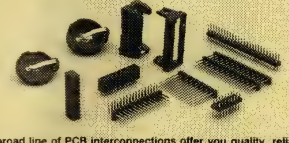

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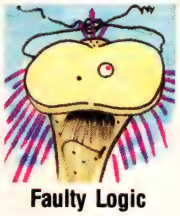

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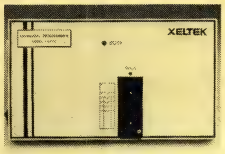

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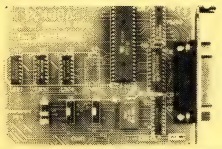

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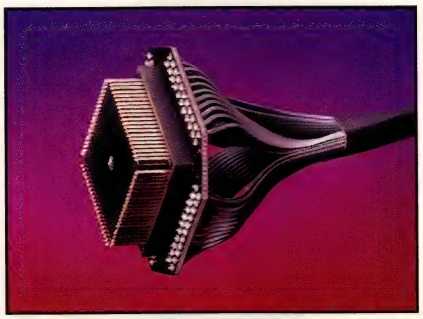

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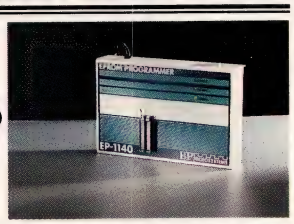

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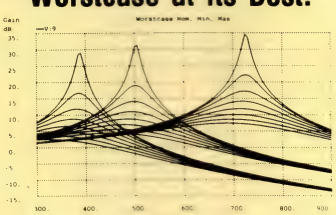

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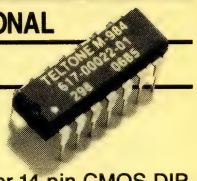

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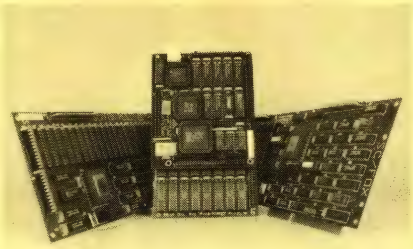

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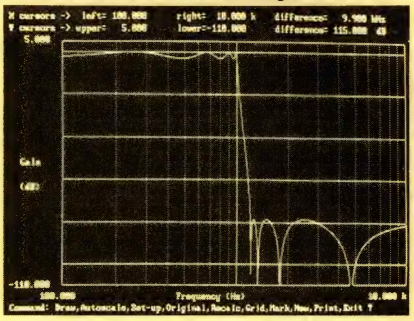

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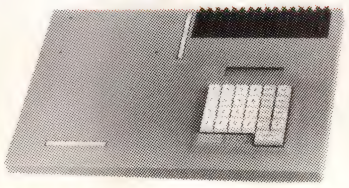

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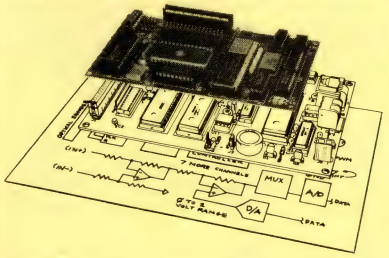

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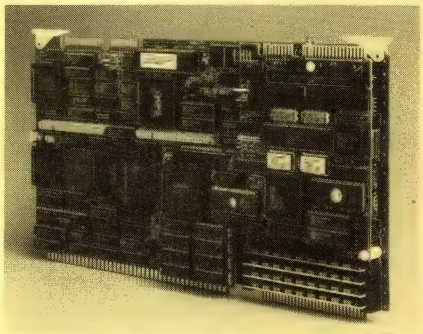

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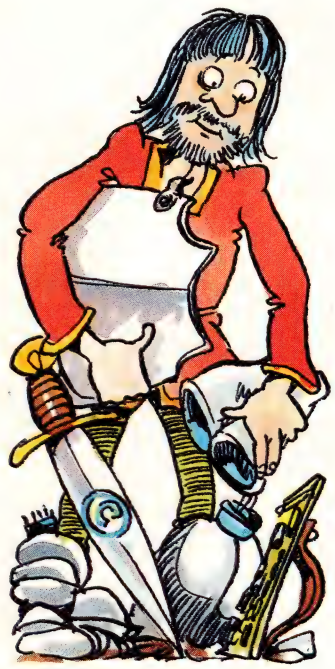
CIRCLE NO 127

Your ideas, your inventions, and your legal rights

Part 2 of this 2-part article focuses on copyrights, patents, trademarks, and the Semiconductor Chip Protection Act.

Jay Fraser, *Associate Editor*

In 1976 Congress passed the current Copyright Act. It states that all "works of authorship" are copyrightable. Works of authorship include not only writings but also blueprints, phonograph records, and audio tapes. For the first time, the act also extended copyright protection to computer programs. The programs can be in source code, object code, or even object code in ROM.

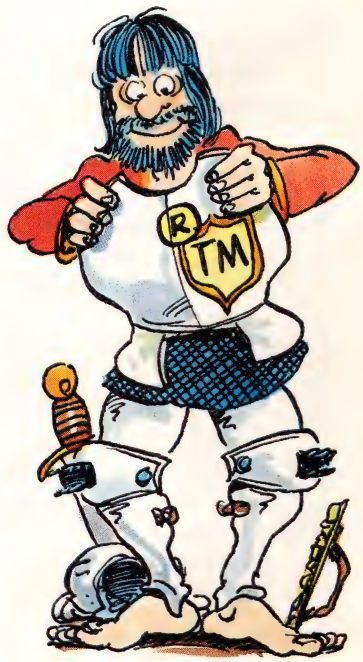


Many people write programs in their spare time, hoping to sell them. But even if you didn't take up company time or use company equipment to develop a program, you still might not own the rights to it. A firm can claim the rights to one of your programs if the knowledge and experience you gained on the job enabled you to write it. A firm can make a stronger claim if your program is directly related to an area you specialize in at work.

If you develop a software program while you're a salaried employee of a company, the best way to protect your rights is with a written agreement. The agreement should state specifically the type of programs you've been hired to write and that the company will retain the rights to only them. You will keep the rights to all others.

If you're a consultant or a freelance programmer, you're probably used to working under contracts. You should still read them carefully. Most contracts state that any software you create for an employer is, in legal terms, work-made-for-hire. In that case, the employer owns the software's copyright. If a contract doesn't include a clause that states this clearly, then you'll retain the rights to any software you write.

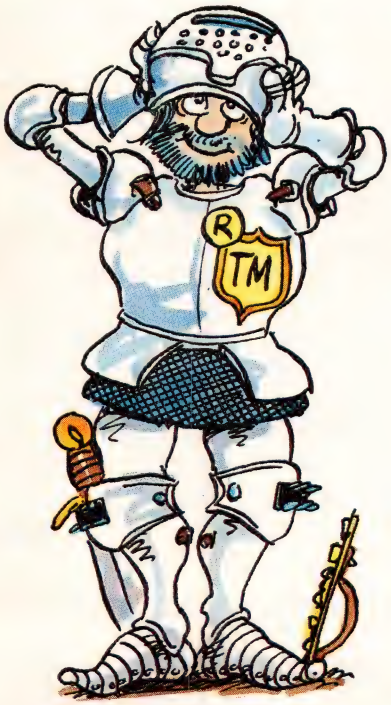
It has now been established by



statute that you automatically have a copyright on any program you write as soon as the program is in a "fixed" form. A "fixed" form is a form that can be read with or without the aid of a machine or device. You don't have to publish or distribute your program to qualify for a copyright.

Even if you haven't formally copyrighted your program and someone infringes on it, you can still file for your copyright, then take the person to court. If you want to sell your program, you should register the copyright. To register the copyright on a computer program, fill out an application form, attach the first and last 25 pages of your listing, and mail it to the Copyright Office at the Library of Congress in Washington, DC. If you have already published the program, the Copyright Office requires two copies of the first and last 25 pages.

You should place the standard copyright notice—the word "Copyright" or the symbol ©, the year, and your name—on all disks, tapes, and ROMs, as well as on any accompanying manuals. You should also insert the copyright notice into the coding, so that it will appear on the screen with the title and will print out when the program is run. A copyright is valid for the life of the author plus 50 years.



Another way you can protect your ideas is with a patent. Patents were created so that inventors could retain the exclusive rights to make, use, and sell their inventions for a limited amount of time, currently 17 years. Patents usually apply to devices and processes, but software can also be patented. If it's part of a larger invention, then it can be included in the patent.

Patents have some serious drawbacks, however. To obtain a patent, you must submit a detailed description of your invention. Once your patent is issued, anyone can pay $1.50 for a copy and use the information to "invent around" your device and perhaps come up with a better one. You also run the risk of some unscrupulous person simply copying your invention. It's up to you to fight infringement of your patent, and you could be in for a long and expensive legal battle.

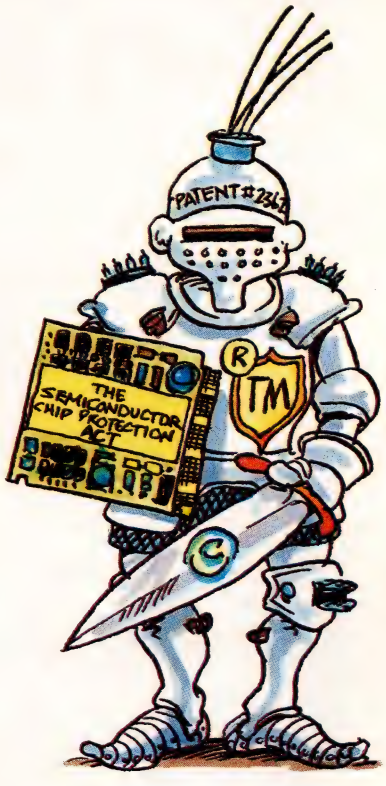
Another drawback to patents is that, unlike copyrights, they're not easy to obtain. The forms are difficult to fill out and your statements have to be carefully worded. You'll probably need the services of a patent attorney to deal with the Patent and Trademark Office.

Your patent may also be infringed by foreign competitors. In that case, legal recourse could be difficult. Laws in foreign countries concerning patents differ significantly from ours. In the United States, if you use, sell, or publish a description of your invention before you've taken out a patent on it, you have a grace period of one year to apply for one. Most foreign countries have no grace period, and in some of them publishing a description of your invention before you have a patent will actually prevent you from obtaining one.

Therefore, consider the pros and cons of patents before you apply for one. If you want to keep the ideas behind your invention strictly confidential, you may be better off relying on the protection of trade-secret laws.

A trademark is a convenient way for the public to identify your products. Each state has its own trademark-registration laws, so if you intend to offer your products for sale in only one state, register your trademark there. However, if you're going to engage in interstate commerce, you should register your trademark with the Patent and Trademark Office in Washington, DC. They will conduct a search through their files, and if your trademark isn't "confusingly similar" to another already being used, you'll have an exclusive right to it. Registering a trademark, like taking out a patent, can be tricky. You may want to consult an attorney who specializes in trademark law.

One more form of legal protection is available to you, but it applies only to semiconductor chips. In the past, chips weren't adequately protected by patents. The manufacturing process could be patented, but



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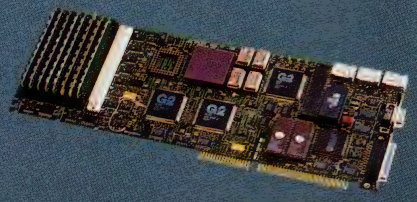

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CIRCLE NO 33

not the design of individual chips. Copyrights weren't any help either. Chips were seen as utilitarian objects and therefore not eligible for copyrights. Because this left an important industry vulnerable to large-scale piracy, Congress passed the Semiconductor Chip Protection Act in 1984.

The Act protects "mask works," which it defines as "a series of related images, however fixed or enclosed" that represent the 3-D geometric features in the layers of a semiconductor chip. Once your mask works are registered with the Copyright Office and offered for sale in the United States, they can't be reproduced in any other chips without your permission.

The penalties for piracy are severe. If a company is convicted of reproducing your mask works illegally, it could be fined as much as $250,000 or forced to pay you all the profits it made from the sale of the chips with your design.

The Semiconductor Chip Protection Act was written so that it doesn't preclude reverse engineering. In addition, chip mask works can be reproduced if they are "solely for the purpose of teaching, analyzing, or evaluating the concept or techniques embodied in the mask work or the circuiting or organization of the components used in the mask work." You have two years to register your mask work after first offering your chip for sale. If you don't register them, your work then falls into the public domain.

Employment agreements, copyrights, patents, trademarks, and the Semiconductor Chip Protection Act all offer you protection for your ideas. All of them also have shortcomings. One may serve your needs better than the others, but if you use their protection skillfully you can retain the maximum amount of control over what you create.

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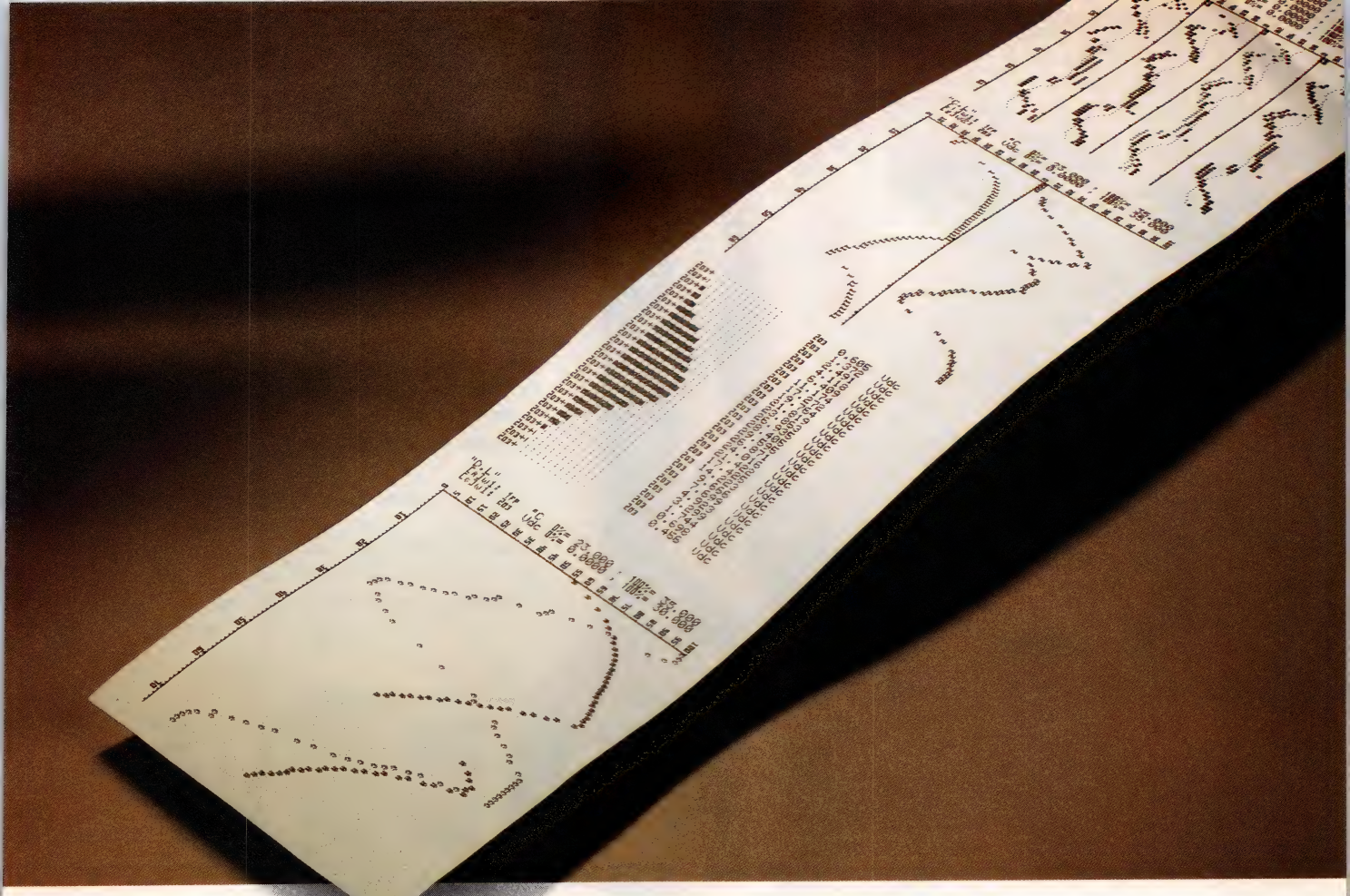

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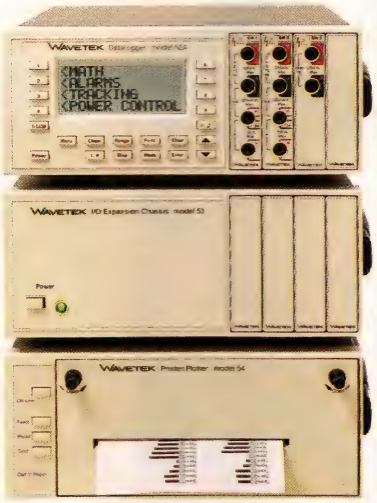

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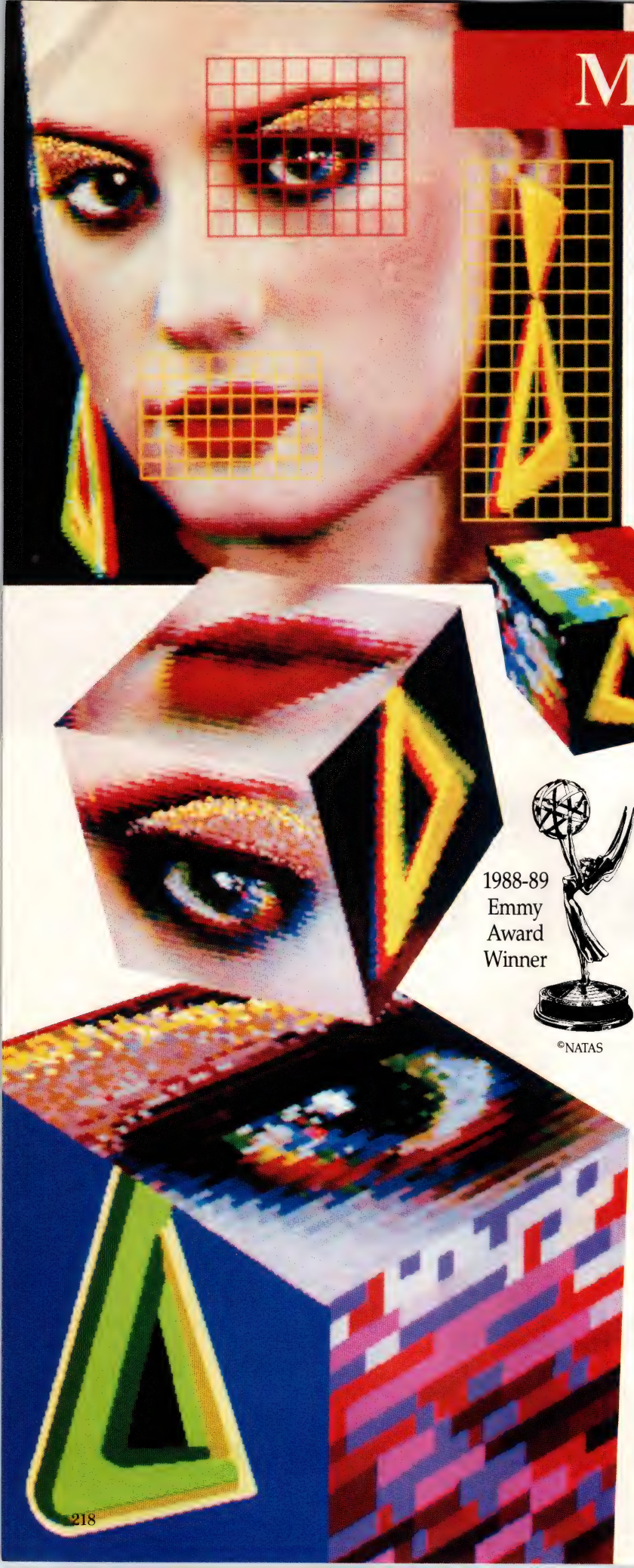

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CIRCLE NO 128

EDN Magazine Edition News Edition

1990 Recruitment Editorial Calendar

Issue	Issue Date	Ad Deadline	Editorial Emphasis
Magazine Edition	Jan. 4	Dec. 14 '89	Signal Processing ICs, Computer Systems, Microprocessors, Software, Calendar of Industry Events
News Edition	Jan. 11	Dec. 19	ICs/Programmable Logic, Aerospace/Defense, Regional Profile: Texas
Magazine Edition	Jan. 18	Dec. 28	Analog ICs, Computer Boards/Microprocessors, Software/Programming, Technical Article Database
News Edition	Jan. 25	Jan. 4 '90	CAE/Software, Medical, Special Supplement: Engineering in the 1990s
Magazine Edition	Feb. 1	Jan. 11	Computer Boards/Microprocessors, Analog ICs, Buscon Preview, CAE Software, Power Circuits
News Edition	Feb. 8	Jan. 19	Instruments/Board Level, System Integration, Special Supplement: Embedded Systems/Microprocessors
Magazine Edition	Feb. 15	Jan. 25	Digital ICs, Computer Systems, Interconnect Technology, Sensors
News Edition	Feb. 22	Feb. 2	CAE/Hardware, Telecom, Regional Profile: No. California
Magazine Edition	Mar. 1	Feb. 8	Computer-Aided Engineering/ASICs, Computers & Peripherals, Digital ICs/Microprocessors, Semicustom ICs
News Edition	Mar. 8	Feb. 15	Analog/ICs, Automotive Electronics, Special Supplement: RISC/Microprocessors
Magazine Edition	Mar. 15	Feb. 22	Analog ICs, Components, Engineering Software, Special Design Project #1
News Edition	Mar. 22	Mar. 2	Optoelectronics, Peripherals, Regional Profile: New York, Pennsylvania & Connecticut
Magazine Edition	Mar. 29	Mar. 8	Software Special Issue—Interface ICs, Software/Programming/Microprocessors/ASICs, April Fools Section, Special Design Project #2
News Edition	Apr. 5	Mar. 16	IC/Logic ICs, Distribution, Special Supplement: Distribution
Magazine Edition	Apr. 12	Mar. 22	Communications Special Issue—Communication ICs, Communication Systems, Microprocessors, Special Design Project #3
News Edition	Apr. 19	Mar. 30	ICs/Graphics Controllers/Microprocessors, Industrial Automation, Regional Profile: So. California
Magazine Edition	Apr. 26	Apr. 5	Computer Boards/Microprocessors, Power Sources, Sensors/Transducers, Special Design Project #4, Electro Show Issue
News Edition	May 3	Apr. 12	CAE/Board Layout, Education, Special Supplement: ASICs, Electro Show Issue
Magazine Edition	May 10	Apr. 19	Analogy Technology Special Issue—Analog ICs, Analog Instruments, Digital ICs/Microprocessors/ASICs, Special Design Project #5
News Edition	May 17	Apr. 27	ICs/Memory ICs, Test & Measurement, Regional Profile: Massachusetts & New Hampshire
Magazine Edition	May 24	May 3	Microprocessors, Computers & Peripherals, Semicustom ICs/ASICs, Components, Sensors & Transducers
Magazine Edition	June 7	May 17	Software, Design Tools, Microprocessor I/O Chips, μP Support Chip Directory
News Edition	June 14	May 24	Peripherals/Input Devices, Software, Special Supplement: EDA
Magazine Edition	June 21	May 31	Computer-Aided Engineering, Computers & Peripherals, Power Semiconductors, Semicustom ICs/ASICs
News Edition	June 28	June 8	ICs/RISC/Microprocessors, Image Processing, Regional Profile: Oregon & Washington
Magazine Edition	July 5	June 14	Product Showcase—Volume I: Hardware & Interconnect, Power Sources, ICs & Semiconductors, Software

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- Administration and Maintenance Software Development
- Line and Trunk Maintenance
- Software Test and Integration
- Software Tools Development and Support (IBM-MVS Environment)

To qualify, you should have a minimum of 3-5 years' experience in Class 5 Central Office Switching Systems Software Development. In addition, you should have a BS or MS in Computer Science/Electrical Engineering or a related area.

Software Development/Hauppauge, New York

- Assembler and/or "C" Language Programming
- IBM Protocol Emulation (Bisync, SNA/SDLC)
- CCITT Protocols (X.3 and/or X.25)
- Software Test and Integration
- UNIX™ Internals

To qualify, you should have a minimum of 2-4 years' experience in development of protocol emulations and/or wide area packet switched network software. In addition, you should have a BS or MS in Computer Science/Electrical Engineering or a related area.

To find out more about positions in Boca Raton, please forward your resume to: Human Resources, Siemens Public Switching Systems, Inc. Dept. EDN, 900 Broken Sound Parkway, Boca Raton, FL 33487. For positions in Hauppauge, please forward your resume to: Professional Staffing, Siemens Public Switching Systems, Inc., Dept. EDN, 89 Arkay Drive, Hauppauge, NY 11788. We are an equal opportunity employer.

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HONEYWELL AND YOU: A WINNING COMBINATION FOR THE 90s AND BEYOND.

Honeywell in Phoenix offers a variety of career opportunities in our Commercial Flight Systems Group. Our continuing growth has created the following positions:

Systems Design Engineer — In this area, you will be involved in guidance and control systems analysis and hardware/software design trade-offs. Specification designs, including guidance, navigation and control algorithm development, as well as systems integration and installation, flight test and customer liaison activity, are a part of these positions.

System Software Development — This area involves development of flight software for advanced guidance and control systems for aircraft using modular and structured programming techniques. You will be involved with algorithms and development of real-time programs in both assembly (8086 family Z8002, 68000) and high order languages such as Pascal, "C," Ada and PLM/86, with subsequent integration with hardware.

Electronics Engineering — These positions involve the development of new processor/bus architectures and specifications to support fault tolerant/redundant airborne applications. To qualify, you should have experience with embedded multiprocessor-based avionics systems.

Display Systems — These positions offer systems, software and hardware opportunities with CRT/LCD display technology. You should be familiar with digital hardware design and/or real-time programming. Systems functions include overall system definition and design and customer interaction.

To qualify for the positions listed above, you should have a BSEE degree or a BS degree in computer science and at least three years of experience.

Manufacturing Engineering — These positions offer support of new product transitions to production, on-going operations sheet and tooling requirements and implementation of floor work teams. You will interface with a number of functional areas and assist in the implementation of shop floor control, SPC and JIT systems. To qualify, you should have an engineering degree in mechanical, manufacturing, industrial or a related engineering discipline, with two or more years of experience in manufacturing engineering or a related product engineering role supporting electro-mechanical or circuit card assembly. Experience in surface-mount technology, SPC and/or JIT implementation is a plus.

Quality Engineering — To qualify for this position, you should have a BS degree in an engineering curriculum. A minimum of two to five years of experience in quality engineering/assurance, reliability and/or product engineering is required. You should have strong communications skills and computer applications experience. Customer interface experience is preferred.

Additional opportunities are available in:

- Avionics Systems Simulation
- CAE Engineering
- Artificial Intelligence
- VAX Systems Administration

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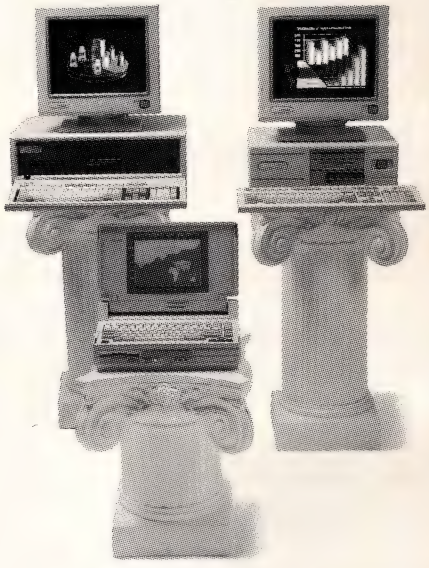

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Our continued success has created immediate opportunities for top PC professionals at our Houston headquarters. Start with a degree and relevant experience. Add to that a strong set of personal values and the desire to do what's never been done before, and you could be part of our winning team.

PCB Supplier Quality Engineer

Start with a BS in a related engineering field and four or more years' experience. In addition, you should have a strong knowledge of vendor relations with respect to printed circuit boards, and have a good SPC background. Excellent communication skills are essential.

Component Supplier Quality Engineer

Put your related engineering degree and four-plus years' experience to the test. You should be familiar with ASIC devices, microprocessors, memory devices and other PC-related components. In addition, you should be able to interface with design, manufacturing and vendors. Good communication skills are required.

TAB Engineer

Along with your related degree and four-plus years' experience, you should be familiar with tape automated bonding processes as they apply to surface mount technology board fabrication. You should also have experience in a high-volume computer-related industry.

Test Engineers

Start with a BS in a related field and two years' experience. In addition, you should have a strong knowledge in one of the following areas: GENRAD 227X series in-circuit testers, TERADYNE L210 functional testers, LASER VG simulation, trillium components testers, ATE fixture design or diagnostic test software development.

Sustaining Engineers – Peripheral, PCB

You'll need a BS in a related field and three years' experience. You should also be familiar with sustaining operations in a high-volume manufacturing environment. In addition, specific knowledge in one or more of the following areas is essential: tape/floppy/hard drives, monitors/displays, keyboards, power supplies/batteries, sheet metal/plastics/tooling, or PCB/SMT assembly.

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COMPAQ

INTEL ARIZONA... THE SITE FOR ALL REASONS.

Intel Corporation, one of the world's largest semiconductor manufacturers, is expanding its Chandler assembly and test manufacturing capabilities. Well-established in the Phoenix area with multiple operations in Chandler, this expansion will provide new and challenging jobs for the right individuals.

Establishing one of Intel's domestic full-scale, totally integrated semiconductor assembly and test manufacturing facilities in the U.S., Intel offers outstanding employment to career minded candidates. We are looking for candidates who will thrive on working in a fast-paced environment in the following positions.

Senior Component Assembly Analyst

MS or PhD in Materials Science, Physics, Chemistry or related discipline and 3-5 years experience in materials and failure analysis of assembled parts to support IC fabrication and advanced assembly of plastic and hermetic packages. Ideal candidate will have strong technical and hands-on capability in SEM/EDX/WDX, FTIR, microhardness and thin films characterization. In addition to providing technical expertise in further understanding of assembly/test related to process and package problems, individuals may publish findings in technical publications.

Software Integration Project Manager

Individual will be responsible for the implementation of an in-house SPC system in component assembly and test. Position requires a background in statistics along with a BS in CS or equivalent and 3-5 years programming experience in a manufacturing environment, i.e. shop floor control systems and large multiuser systems. Must be proficient in Cobol, C or similar high level programming languages in a VAX/VMS, DOS, DBMS environment. A good understanding of MRP II and integration of independent systems is beneficial.

Senior Programmer Analyst

This position requires a BS in CS or equivalent and 3-5 years programming experience in a manufacturing environment. Must be proficient in Cobol, C or similar high level programming languages along with expertise in COMETS/VAX environment. Responsibilities will include working with users to develop requirements for reporting systems and providing programming support to integrate PC based equipment station controllers to shop floor control systems.

Production Supervisors

Will plan activity, supervise, motivate and evaluate personnel as well as ensure achievement of aggressive production schedules. 4+ years experience in the semiconductor industry is required. Direct production line supervisory experience within the past 2 years is preferred. BA/BS a plus.

Industrial Engineer

Will establish and improve work methods while implementing tooling and fixtures to increase the productivity on major manufacturing equipment. BS/MS in IE or equivalent. Experience in the semiconductor industry is preferred; MBA a plus.

Vision Inspection Process Engineer

BS in Physics or Mechanical Engineering is required as is solid knowledge in computer software/hardware applications. Computervision and CAD knowledge is desirable. Primary responsibility will be to maintain and improve current and future vision inspection systems for component assembly manufacturing.

Mold Process Engineer

BS in Mechanical Engineering, Polymer Engineering, Industrial Technology or equivalent and 3-5 years experience in component assembly manufacturing is required. Must have a good knowledge/experience in mechanical, hydraulic, pneumatic and electrical control systems. Primary responsibility will be to maintain and improve the molding yields via process control. Automold experience is desired.

Deflash, Trim & Form (DTF) Process Engineer

BS in Mechanical/Manufacturing Process Disciplines or equivalent years experience. Must have extensive knowledge in lead forming and DTF tooling design theory. Will be responsible for evaluating, understanding and improving specific DTF processes/systems for PLCC and PQFP products. Experience with microprocessor controlled automold equipment a plus.

Wire Bond Technicians

Must have AA/AS degree in Electronics and 2-6 years experience troubleshooting wire bonding, saw dicing and die bonding equipment. Will be assisting engineers with hardware/software modifications; Lotus PC skills preferred. Knowledge of plastic package assembly is a definite plus. Requires working off-shift.

Die Prep Engineer

BS in EE or ME and 2-6 years in FOL component assembly including PC literacy in DOS and Lotus. Primary responsibilities will be to characterize equipment and process to maximize product yields, equipment uptime and optimize product output. Thermal compression wire bonding process experience and microprocessor controlled automated saw dicing and die bonding equipment is a definite asset.

Die Attach Engineer

BS in EE or ME and 2-6 years experience in component assembly including PC literacy in DOS and Lotus. Thermal compression wire bonding, saw dicing and die bonding will be a plus. Must be knowledgeable in product/package reliability, basic wafer fabrication and semiconductor device testing.

Wire Bond Engineer

BS in EE or ME and 2-6 years experience in FOL component assembly including PC literacy in DOS and Lotus. A background in thermal compression wire bonding is desired. Must be knowledgeable in product/package reliability, basic wafer fabrication and semiconductor device testing.

EOL Engineering Technician

Individual will be assisting engineers in the modification and upgrade of EOL component assembly equipment. Position requires AA/AS degree in Electronics or equivalent and 2-6 years experience on conventional mold, trim and form, and laser mark equipment. Automold experience is a definite plus.

EOL Maintenance Technicians

AA/AS degree in Electronics or equivalent and 2-6 years experience maintaining conventional mold, trim and form, and laser mark; automold experience is a plus. Must be willing to work off-shift.

Laminated Ceramic/Cerdip Engineer

BS in EE or ME and 3-6 years experience in component assembly. Must have a solid background of saw-to-seal operations and extensive gold wire bonding experience. Process or equipment engineering experience with K&S 1482 wire bonders, specifically, would be very beneficial. Must be capable of both production troubleshooting and process development. Statistics background also useful.

We welcome your interest in Intel...please send your resume to: ***Intel Staffing, Dept. A534, 5000 W. Chandler Blvd., Chandler, AZ 85226.*** An EEO employer, actively seeking m/f/v/h candidates.

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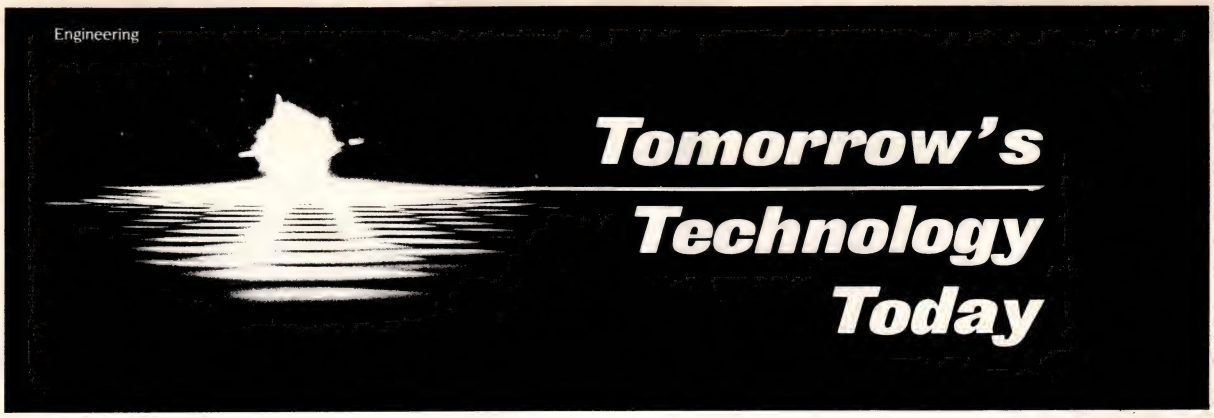

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There's a new wave of telecommunications technology on the horizon, and **Rockwell International** is committed to its continuing success. We've combined divisional operations to create **Rockwell Communication System** organization which allows us to apply our proven knowledge to customer-driven products of the future.

We are seeking talented and experienced individuals interested in advancing their careers in the progressive telecommunications industry. We presently have several exciting opportunities available for top technological professionals in our **Switching Systems Division** located at our Downers Grove facilities. We invite you to consider any of the following positions which could direct your professional future to **Rockwell International!**

Software/Hardware Engineer Group Leader

This aggressive group leader will steer achievement-oriented design team in the development of microprocessor controlled equipment. Microcomputer implementation and "C" software experience required.

Software Engineer - Relational Database

Position entails measuring and improving the overall performance of relational database system in a real time multitasking environment, as well as the use of relational database in a telecommunications application.

Software Engineer - System Test (2 positions)

Responsibilities include the design and development of automation tools in the UNIX*/SUN system using "C" and shell, along with the creation of new feature test plans. Telephony experience is desirable. PC experience is helpful.

Software Engineer - Galaxy ACD (5 positions)

Provide technical assistance and leadership in feature definition and development. Will be involved in system definition, high level and detailed software design and modification of existing products.

Software Engineer - PC Applications (2 positions)

Responsibilities include the provision of technical assistance in development of PC-based applications. Will be involved in systems definition, high level and detailed software design, and modification of existing products. Extensive MS-DOS experience required.

Software Configuration Engineer

Will develop policies, procedures and practices for software configuration management, prepare related documents and charts for the reporting of activity metrics, and provide hands-on and printed material for training of the user community. Additional responsibilities include working with various computer systems for documentation preparation, database setup and maintenance, and generation of various electronic, magnetic media forms such as tapes, disks and cassettes.

UNIX* Systems Programmer

Develop system performance measurement tools, network utilities, and administration environments for UNIX*-based VAX and SUN systems. Will also plan, implement and test changes to the system environment.

Senior Hardware Design Engineers

Multiple openings exist in the hardware design group which support both current and future products. We are seeking individuals to work in the following areas:

OEM Engineer (1 position)

Will work on projects that require the integration of state-of-the-art OEM equipment into Switching System products.

EMI Engineer (1 position)

Must conduct EMI related system testing, as well as possess experience in designing electronic equipment to stringent EMI standards.

Regulatory Standards (2 positions)

Will define hardware requirements for switching systems so that they will be compliant to a variety of current and evolving domestic and international regulatory standards.

Product Development Engineers (3 positions)

Responsibilities include the development and trouble-shooting of digital hardware subsystems and assemblies for switching systems. A familiarization with regulatory standards and microprocessors-based subsystems is a plus.

Hardware Design Engineer (2 positions)

Design special services transmission equipment in analog and/or digital. Will be responsible for taking products from conception through production. VF transmission and signaling applications, microcomputer implementation and firmware experience helpful.

Component Application Engineer - Material Analyst

Perform material qualification and failure analyses, write analysis reports, maintain lab facilities and provide engineering staff assistance.

Component Application Engineer - Value-Added Engineering

Provide technical support to OEM/Value-added engineering. Will be involved with developing procurement specifications, evaluating products to qualify suppliers and data base maintenance. Also provide assistance to the material and manufacturing organizations.

Strategic Product Planning Manager

Responsible for managing and developing WESCOM integrated network systems long range product and market plan. Additional functions include prospective market competitive research, business planning and analysis. A B.S. in a Technical or Business discipline (MBA desired) and a minimum of 5 years experience in a related field with a concentration in a management capacity. An in-depth knowledge of telecom industry with an emphasis on both public and private networks is necessary.

All of the above engineering opportunities require a B.S. or M.S. in computer science or electrical engineering and appropriate related experience.

Rockwell International employees benefit from exciting challenges and outstanding rewards including an excellent growth opportunity. We offer a competitive array of benefits and an overall competitive salary structure. For more information, please submit your resume indicating position of interest to: **Employment Manager, Rockwell International, 1431 Opus Place, Downers Grove, IL 60515. Equal Opportunity Employer M/F.**

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Software Opportunities

Software Engineer

You should have a BSCS/BSEE and 3+ years' experience with C, network programming with multitasking operating systems, structured programming techniques and software tools. Experience with DOS, OS/2, LAN Manager, and network programming is preferred. Some experience with relational data base is desirable.

You will be responsible for the design and development of data collection applications.

Printer Software Engineer

You should have a BS in Electrical Engineering or Computer Science and 3 years' real-time embedded software development experience. You should be fluent in C and experienced with software development methodologies. We would prefer knowledge of C++, UNIX, Sun Workstations, VRTX, data communications and Assembly language. Experience in software design of printers desirable.

You will contribute to the teams efforts in the development of printer product software and the definition of new products.

Software Test Engineer

You should have a BSEE/BSCS and 1+ year real-time embedded software development experience. We prefer knowledge of C programming, software test methodologies, 80186 microprocessor and Assembly programming, software development and UNIX experience.

You will plan test strategies, ensure testability in software design and coordinate test equipment setup. Developing automated test programs, suites, software test plans and procedures is also your responsibility. In addition, you will conduct test execution, document the results and coordinate the software problem reporting and tracking.

Senior Software Engineer

You should have a BSEE/BSCS and 4 years' experience in real-time embedded software development with C and Assembly programming, UNIX workstations, and in-circuit emulators. We prefer experience with Intel microprocessors (80188/80186), object oriented design and programming with C++.

You will be responsible for developing real-time embedded software, contributing in all phases of the project life cycle. This includes developing specifications, scheduling, prototyping, designing, coding and debugging software, integrating software and hardware, testing, and technical support.

Hardware Opportunities

Electronic Engineer

You should have a BSEE and 4-5 years' digital and microprocessor electronics design for microprocessor-based electronic products. Familiar with design, debugging and documentation of high volume, cost sensitive electronic products.

You will have a working knowledge of ECAD, Futurenet, ASIC, analog design, and local area network communications. Some C or Assembly programming experience preferred. Expertise in management of ESD, EMI and environmental problems. Power supply design experience required.

Electronic Design Engineer

You should have a BSEE and 8+ years' design experience with strong digital, analog, and microprocessor design skills. You must have proven project engineer skills with high self motivation. Data communication and computer peripheral electronics experience preferred. Switching power supply design experience a real plus.

You will assume both design and project engineering responsibilities for development of RF Data Collection products. You will design primarily digital microprocessor-based products with the normal degree of analog circuitry in power supplies and interface circuits.

Mechanical Engineer

You should have a BSME, or equivalent and 3-5 years' experience with 2D or 3D mechanical CAD systems, developing complex designs including sheet metal, molded plastic and cast parts. Experience in non-impact printers/thermal printing or label systems preferred.

You will be responsible for detailed design, testing and documentation of various mechanisms and subsystems from conceptual phase of new product design through completion of modules. This will include scheduling, documentation and supporting designs into production.

Mechanical Engineer

You should have a BSME or equivalent technical experience and education and 3 years' experience in designing enclosures and hardware for electronics products. Must have knowledge of injection molding, sheet metal and die casting. This position requires the ability to apply advanced drafting techniques and knowledge to solve practical, mechanical and fabrication problems.

You will perform mechanical design assignments to support new product development and assist in the development of complex product designs, scheduling and quoting.

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- **Embedded Applications**
- **DOS or OS/2 Applications**
- **Real-Time Applications**
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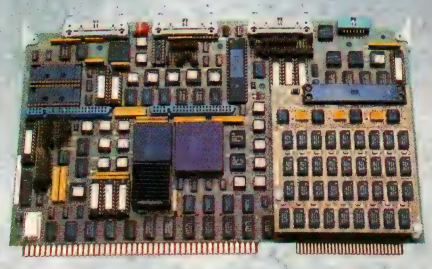

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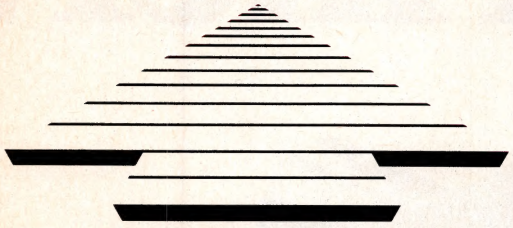

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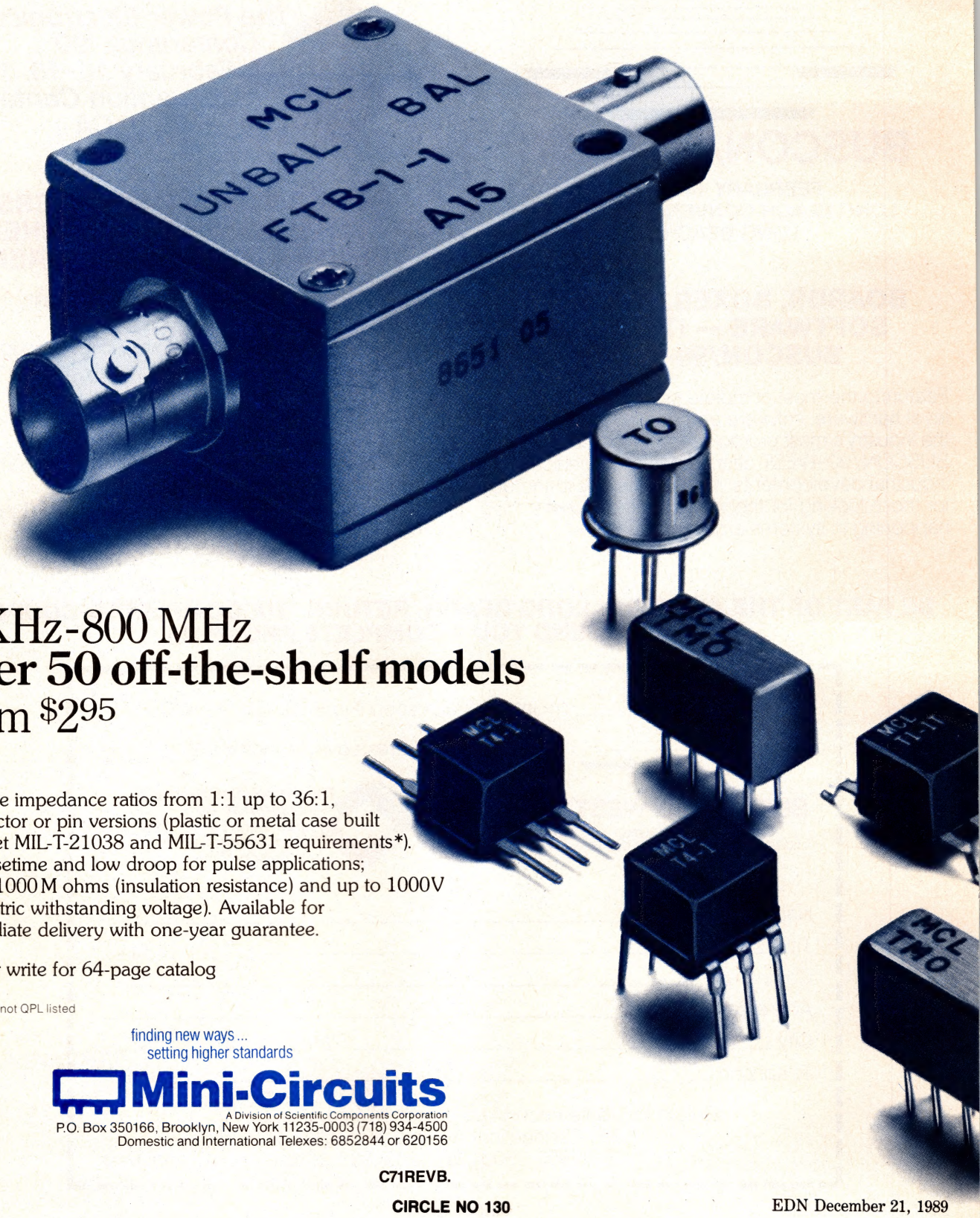

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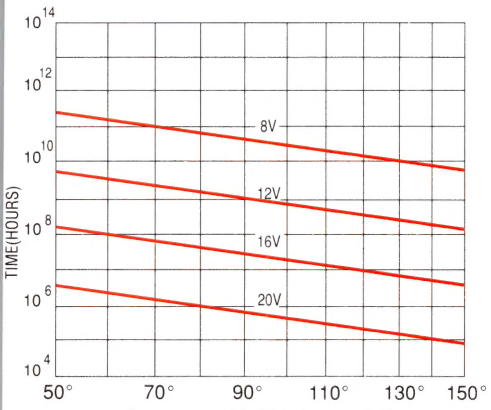

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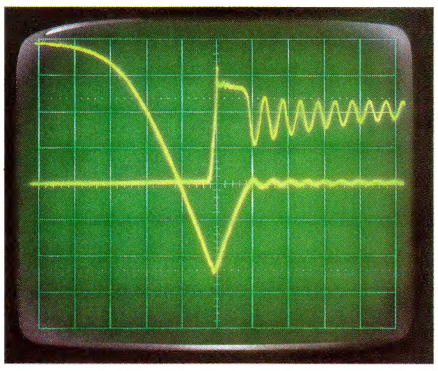
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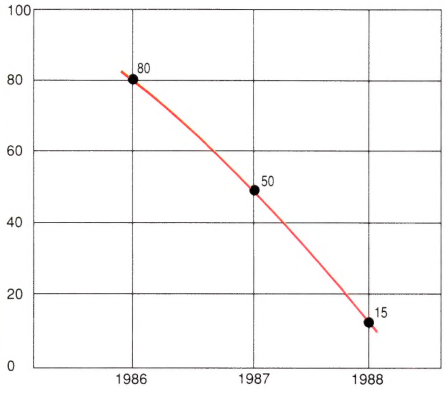

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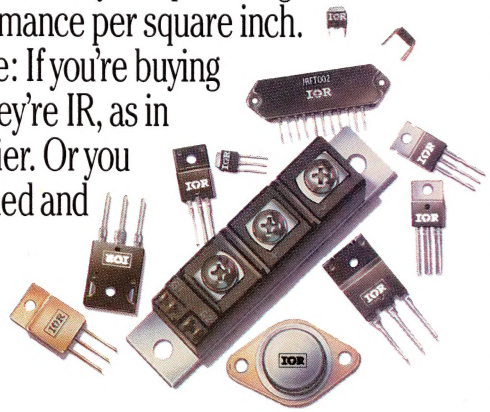

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